Armed Forces Radiobiology Research Institute

Population Health in Regions Adjacent to the Semipalatinsk Nuclear Test Site

Institute of Biophysics
Moscow, Russian Federation

Physical Technical Center
Sarov, Russian Federation

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Preface

On August 29, 1949, the then Soviet Union conducted the first of 118 atmospheric nuclear tests on the Semipalatinsk Test Site, or Polygon as it was known. Thirty tests, including five in which the nuclear unit failed to trigger, were surface nuclear explosions, defined by the scaled height $\bar{h}$ being less than $35 \, {}^{m}/_{kt}{}^{1/3}$ ($\bar{h} = {}^{h}/_{\sqrt[3]{w}}$, where h is the height in meters and w is the yield in kiloton TNT equivalent). The remaining 88 were conducted at much higher scaled heights ($\bar{h} >> 35 \, {}^{m}/_{kt}{}^{1/3}$) where the fireball did not come near the ground and therefore the fallout was much less.* Some tests, especially the explosions in 1949, 1951, and 1953, spread more contamination than others.

As the authors of this report point out, the first systematic review of the health of the population took place in 1956 under the auspices of the USSR Ministry of Health. Two dispensaries, the functions of which initially were classified, were established. Dispensary Number 4 is in Semipalatinsk and Dispensary Number 3 was in Ust'-Kamenogorsk. The latter was closed in 1960. A comprehensive expedition was conducted in 1958 to examine people in Pavlodar and Karaganda oblasts (the political equivalent of a state or province) as well as those in the oblasts of Semipalatinsk and East Kazakhstan. In 1959 special expeditions were conducted in the settlements of Dolon, which were heavily contaminated by the 1949 test, and Sarzhal and Kainar, which were heavily contaminated in 1953. Details of these and other expeditions conducted by the Ministry of Health and the Ministry of Defense are summarized in other publications. The authors document how advancing knowledge and tighter control over the years resulted in the lowering of the permissible exposure dose (PED). Initially, in 1946, the PED for both workers and population was 60 rem (0.6 Sv)/year. By 1987, however, the PED had been lowered to 5 rem (50 mSv)/year for workers and 0.5 rem (5 mSv)/year for the general population. Although standards were not always followed, it is clear that over the years there was increased awareness of the potentially deleterious effects of exposure to ionizing radiation and there were attempts to protect not only workers but also local inhabitants against these effects.

The crucial fact documented in this report is that the health of the people in the regions surrounding the test site was poor. The authors compiled data relating to incidences not only of neoplastic diseases but also cardiovascular diseases, infectious diseases, nervous system dysfunctions, etc. Heavily exposed settlements were compared with control villages. Of note, however, is that not one case of acute or chronic radiation sickness was detected.

The report's importance is that it thoroughly addresses questions about the cause(s) of the population's severe health problems. The authors' careful analyses of factors associated with increased incidence and/or susceptibility to disease are described in detail.

One factor, exposure to ionizing radiation, is discussed at length, and pertinent food contamination and dosimetry data are presented. The authors

*Dubasov Yu.V., Zelentsov S.A., Krasilov G.A. *et al.*, Chronological List of the Atmospheric Nuclear Tests at Semipalatinsk Test Site and Their Radiological Characteristics. Paper presented at 1st International Workshop on RADTEST Project in Vienna, Austria, 1/94.

point out that the degree of symptoms recorded did not correlate with the exposure doses. At the same time, they note that observed changes in individual hematological indices could be attributed to the effects of fallout.

It is apparent that most of the illnesses discussed have other potential causes, which are described. Poor and often improper diet is detailed. The social and economic impact of World War II (1941–1945) profoundly affected the availability of food as well as the entire infrastructure of the largely agrarian economy. Sanitary and hygienic standards were often well below the norm. Medical service to this region, particularly in the rural areas, varied from inadequate to nonexistent. There was insufficient water for household needs, and even the water piped to major cities was inadequate. All of these conditions can affect the health of a population, and many of the health problems described could be attributed as easily to one or more of these factors as to radiation exposure.

AFRRI published this report to facilitate the dissemination of the analysis of these important data for critical review and evaluation. The scientific community would further benefit from the collection, analysis, and presentation of additional health and dosimetric data on the inhabitants of the three most contaminated settlements—Dolon, Kainar, and Sarzhal.

This document and the collection, presentation, and conclusions derived from the data are entirely the work of the authors. Aside from grammatical corrections and conversions of radiation units to current standard units, AFRRI did not collaborate in this report. Editorial changes to improve readability were reviewed to ensure they did not alter the scientific content. Consequently, the opinions expressed in this document are entirely those of the authors and do not represent those of AFRRI, the United States Department of Defense, or the United States government.

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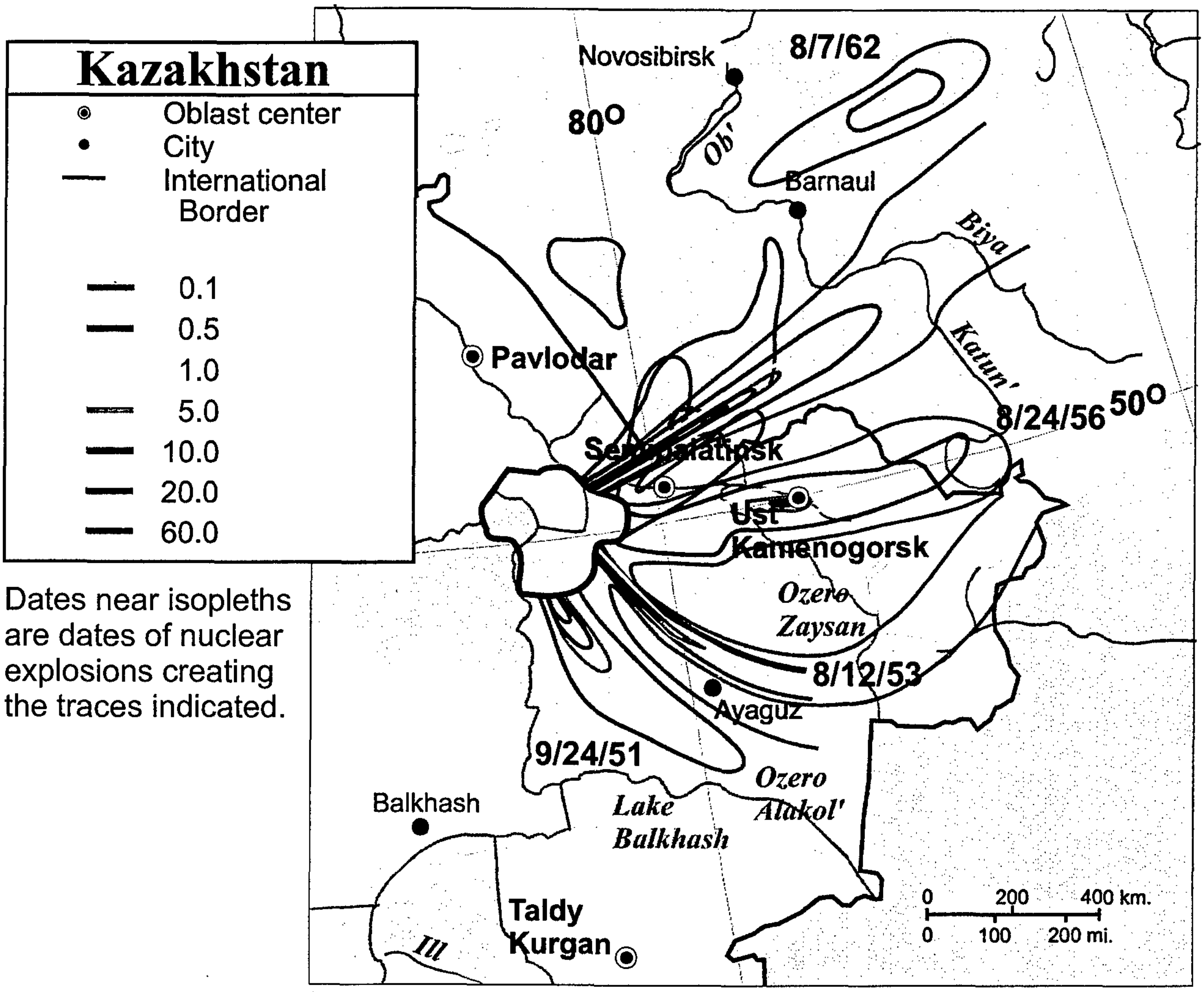
Contents



Dates near isopleths are dates of nuclear explosions creating the traces indicated.

Map 1


Kazakhstan
National capital
Oblast center
City
International border
Oblast border
Disputed border
Railroad
0 200 400 km
0 100 200 mi
Russia
Surgut
Ob'
Yenisey
Perm'
Tura
Irtysh
Yekaterinburg (Sverdlovsk)
Ishim
Chulym
Krasnoyarsk
Tomsk
Novosibirsk
Chelyabinsk
Omsk
Samara (Kuybyshev)
Saratov
Volga
Belaya
Orenburg
Petropavlovsk
Kustanay
Kokchetav
Barnaul
Biya
Katun'
Ural'sk
Chapayev
Tobol
Pavlodar
Rubtsovsk
Ekibastuz
Semipalatinsk
Aktyubinsk
Tselinograd
Arkalyk
Temirtau
Karaganda
Ust'-Kamenogorsk
50°
Astrakhan
Gur'yev
Ural
Ayaguz
Ozero Zaysan
Dzhezkazgan
Aral'sk
Beyneu
Balkhash
Lake Balkhash
Ozero Alakol'
Shevchenko
Leninsk (Tyuratam)
Saryshagan
Aral Sea
Taldy Kurgan
Caspian Sea
Kzyl-Orda
Syr Dar'ya
Ili
Yining
Khorogos
Chu
Nukus
Uzbekistan
Turkestan
Dzhambul
Alma-Ata
Baku
Tashauz
Urgench
Chimkent
Bishkek (Frunze)
Ozero Issyk Kul'
Koria
Krasnovodsk
Aksu
Nabit-Dag
Tashkent
Kyrg.
Turkmenistan
Navoi
Dzhizak
Andizhan
Fergana
40°
Bukhara
Chardzhou
Samarkand
Khudzhand
Yarkand
Karshi
Kashi
Iran
Ashkhabad
Tehran
Mary
Amu Dar'ya
Dushanbe
Tadzhik
China
60°
Termez
Afg.
70°
Pak.
80°
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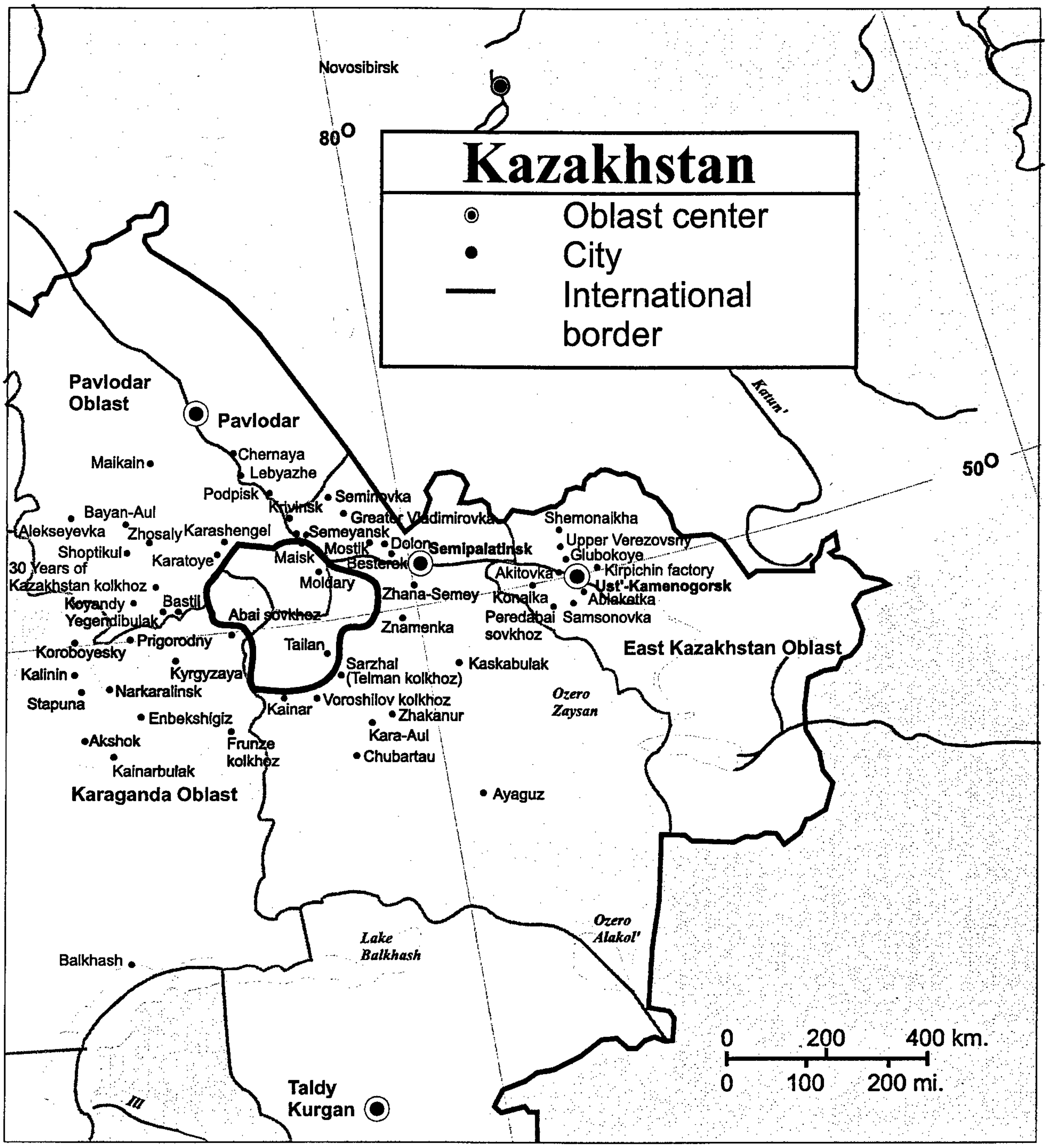
Map 2



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Map 3

Introduction

During U.S. President William Clinton's visit to Russia in January 1994, several documents were signed that shaped potential collaboration by the two countries in environmental studies and the impact of radiation on a population [1]. In particular, agreement was reached on a joint study of the impact of nuclear tests on a population. This collaborative effort will help scientists from both countries gain a scientifically valid understanding of radioactive contamination in territories adjacent to nuclear test sites, the probable exposure doses for the populations, as well as the impact of ionizing radiation on a population living in a contaminated area for many years. The Defense Nuclear Agency (DNA) Contract 001-94-C-0121 dated 7 July 1994 established the requirements for the research effort.

The previous report [2], stage 1 of the research, provides the results of the analysis of archived material and medical examination data obtained in the 1950s and 1960s from the USSR Ministry of Health (Minzdrav) and the Ministry of Defense (Minoborona) expeditions to the regions around the Semipalatinsk nuclear test site. These archived materials are unique. Current data on population health near the nuclear test site zone and archived data can therefore be compared and assessed objectively.

We thank all specialists involved in the complex medical examinations of the inhabitants in several Kazakhstan regions. It is impossible to name the participants of these activities but we must name those who took part in almost all of them: A.N. Marej and A.F. Kobsev, heads of the expeditions; A.I. Shorokhov, O.G. Sobolev, P.Ya. Dunaev, physicians; Yu.V. Venitzkovskii-Zolotykh, M.V. Steputcheva, A.P. Miloserdov, hematologists; M.A. Volodin, A.A. Volkov, S.M. Kachanov, neuropathologists; and Y.S. Stepanov, S.L. Turapin, Ju.I. Bogdanov, G.U. Obvintzev, physicists.

The reports on the examinations of the inhabitants are of great scientific, practical, and social importance.

Examination of the Kazakhstan Population in Radioactively Contaminated Territories: A Historical Note

In recent years in some Kazakhstan and Russian Federation regions (Altai district, Republic of Altai, Kemerovo region, and others) the observed deterioration of the health of the people has been attributed to activities at the Semipalatinsk test site (STS) where nuclear tests were conducted for 40 years. Objective evaluation of the impact of these tests on the population and the analysis and summary of the results of complex medical examinations of the inhabitants who were contaminated with radioactive fallout in different periods will be of great assistance. The history of these examinations requires attention.

STS activities may be characterized by two periods: first, in 1949–1962, the period of nuclear tests in the atmosphere (surface and air tests), and second, when underground nuclear tests were conducted from 1963 until they were discontinued in the late 1980s.

During nuclear tests in the atmosphere, radioactive fallout was observed many times outside the test-site zone. Radioactive contamination was mainly recorded in several settlements in Semipalatinsk, Pavlodar, East Kazakhstan, and the Karaganda regions of Kazakhstan and the Altai district of Russia. However, the degree of radioactive contamination differed, and it depended not only on the explosion type and yield but on how far the settlements were from the test site.

Leaders of the test took particular safety measures to protect participants and inhabitants of the settlements in the vicinity of the site. The protective measures varied in scope and were perfected by accumulated experience in work with radioactive substances and with increased levels of scientific knowledge about the biological effects of radiation. The radiation safety service at the test site predicted the area of radioactive fallout before each test and took into account the meteorological situation in the test site zone and the explosion type and yield. In the event that intensive fallout was predicted in any settlement, the inhabitants were moved temporarily to safe regions. In 1953 for example, inhabitants of Sarzhal were settled in a safe zone and returned 19 days later when the radiation level was considerably reduced due to short-lived isotope decay.

Personnel at the test site constantly monitored the radiation environment in the vicinity of the test zone and measured *in-situ* radiation levels. Before 1956, however, there was no systematic observation of the health status of those who were living in the contaminated zones. Thus, in 1949 after the first nuclear test, 10 inhabitants were examined only once in the settlement of Kanonerka. After the first thermonuclear bomb test, nearly 200 inhabitants in the settlement of Abai and adjacent farms were examined by test site medical personnel.

Systematic radiation surveys and population health surveys of the most contaminated settlements started in 1956. Dispensary Number 4 was established for this purpose by a USSR Minzdrav order dated March 26, 1956. This dispensary functioned until the breakup of the USSR in 1991. These activities are currently provided by the Kazakhstan Radiation Medicine Center. The same order established Dispensary Number 3 in the city of Ust'-Kamenogorsk. The dispensary was closed in 1960 when it was no longer needed.

The first complex medical examinations of inhabitants in several settlements in the Semipalatinsk and East Kazakhstan regions were conducted in autumn of 1956. A team of medical personnel with different specialties who worked in the USSR Minzdrav and

Minoborona systems was involved in the activities. This team also included personnel from the test site and Dispensary Numbers 3 and 4. The trip was organized after a message had been received about the significant increase in radiation background (almost by an order of two) in Ust'-Kamenogorsk after the nuclear test on August 24, 1956. The medical group from the Institute of Biophysics started examining people in the city and its vicinity on September 5, 1956, and continued during the entire period when most commonly expressed changes in blood and general clinical features of acute radiation sickness could appear. The results of these examinations and municipal medical institution data show that no symptoms of radiation sickness were revealed in the inhabitants [3].

This first expedition to examine populations in the Semipalatinsk and East Kazakhstan regions was the start of complex medical examinations of inhabitants in the immediate vicinity of the STS and were conducted by USSR Minzdrav specialists.

In the spring and autumn of 1957 the inhabitants of the settlements in these two regions were examined for the second time [4]. Primary radiation survey data was processed by the test site safety service before each complex examination and directed attention to the inhabited settlements that were subjected to the most intense radioactive contamination.

In 1958, in addition to the twice-examined populations in settlements of the Semipalatinsk and East Kazakhstan regions, people were also examined in the Pavlodar and Karaganda settlements where negligible radioactive contamination was experienced in 1956 [5].

The 1958 expedition was the most comprehensive in terms of the number of physicians and specialists: a neuropathologist, a dermatovenereologist, a gynecologist, specialists in infectious diseases including brucellosis and tuberculosis, hematology assistants, radiologists, radiometrists, radiochemists, physicists, dosimetrists, technicians to do sampling, and others—a total of 161 physicians and specialists. A vast amount of work was done. From June 5 to August 5, 1958, 1,138 individuals (including 50 school children) were examined in 19 settlements; 700 blood samples were analyzed; 4,116 environmental samples were taken and studied; and an *in-situ* gamma survey by automobile was taken along a 2,810-km road. Inhabitants of the Dolon settlement were examined for the first time 9 years after radioactive contamination.

After the 1958 expedition, the USSR Minzdrav decided to conduct medical examinations of the population living in the areas of radioactive contamination by expeditions every two years. Dispensary Number 4 was appointed to monitor the radiation environment and population health in these areas and had to continue to observe those individuals registered during the course of medical examinations in 1956 and 1957.

In May and June of 1959, the USSR Minzdrav expedition examined the inhabitants of Dolon and Sarzhal, the territories subjected to the highest radioactive contamination in 1949 and 1953, respectively. Inhabitants were also examined in Kainar where the gamma dose did not exceed 11 R in open terrain until the radioactive substances completely decayed. This decision was made because the 1958 examination results confirmed the unsatisfactory health status of Kainar inhabitants. The settlement of Shadvinsk in the Pavlodar region served as the control because this territory was not exposed to radioactive contamination according to the report of the radiation safety service at the site. Dolon inhabitants who had gone there after 1954 were also studied as controls. A total of 1,767 individuals were examined. Physicians, neuropathologists, radiologists, hematologists, an oculist, an otolaryngologist, a gynecologist, and a dermatologist participated in the expedition. They studied the morphological contents of peripheral blood, vitamin C contents in the blood, gastric juices, electrocardiograms, and fluoroscopies of the organs of the thorax, and did some biochemical analyses. The examination scheme and methods were the same for the inhabitants of these settlements.

Routine examinations of the population in the contaminated areas of Kazakhstan were conducted by USSR Minzdrav specialists in 1960 and 1962. Permanent radiation surveys and health controls were established in the most contaminated settlements by specialists of Dispensary Number 4 and the test site. Complex medical examinations for radioactive contamination showed no cases of acute or chronic radiation sickness.

In addition to the USSR Minzdrav expeditions, specialists from the regional Institute of Pathology of Kazakhstan (Academy of Science) together with

representatives of the Republic Ministry of Health (Kazakhstan's Minzdrav) examined some Kazakhstan populations. Thus, in 1958, inhabitants in several settlements of Semipalatinsk, Pavlodar, Karaganda, Akmolinsk, and Taldy-Kurgan regions were examined [6]. The services of medical personnel of various specialties were also enlisted. During this expedition, as in the USSR Minzdrav expedition, no cases of radiation sickness were recorded, and the changes noted in the people's health were similar to those observed by USSR Minzdrav experts.

The analysis of the results obtained by the expedition from the Kazakhstan Minzdrav and the Regional Institute of Pathology draws attention to some tendentious conclusions arrived at by the Republic of Kazakhstan and regional specialists. They explained the observed deviations in people's health as results of the impact of radiation and said nothing about sanitary and socioeconomic factors. The examination results do not present data on the sanitary state of inhabited settlements, living conditions of the inhabitants, nor the quality of food—dominating factors in the development of some diseases. How these factors affected the observed decline in the health of the people was not considered.

Earlier dose estimates contained uncertainties that resulted from considerable scattering of active isotopes around the bore pit as well as errors in radiometrical measurements of low-level samples in comparison to background. Instrumentation was also relatively insensitive. Unacceptable errors were registered in radiation environment predictions that were caused by errors of data extrapolation over the 10-year interval after the explosion.

Furthermore, the Kazakhstani specialists did not account for local pathology in population examinations. Some of these peculiar features were noted both by the USSR Minzdrav expeditions in the 1950s and 1960s and by an interinstitutional commission headed by academician A.F. Tzyb who was working in the Semipalatinsk region in May 1989 [7]. This commission assessed population health and hygienic, environmental, and radiation situations in the areas close to the nuclear test site.

Neither the USSR Minzdrav expeditions nor the Kazakhstani specialists had a single plan in mind for examinations that would define the scope, goals, and terms for the work as well as the observation points. Furthermore, there were no united nor coordinated examination methods. Efforts were therefore doubled, and the peculiarities of radioactive contamination of the inhabited settlements were not accounted for in the examinations. Acquired data were not compared, and the examination materials were not correlated. Thus, the need arose to centralize all efforts on evaluating the radiation environment and observing population health in the most contaminated areas in accordance with a coordinated program and common methods.

USSR Dispensary Number 4 was appointed to this work because its employees and specialists from the USSR Minzdrav Biophysics Institute had monitored the radiation and sanitary environment around the test site as well as the health of the people who were living in the local zones of radioactive fallout.

To monitor the environment, the employees from the dispensary annually analyzed over 1,500 environmental samples (soil, vegetation, water, food, etc.). The sampling was done quarterly in the settlements of Sarzhal, Dolon, Chagan, Sarapan, Kanonerka, Berezka, Mostik, Semiyarka, and others. Several experiments were conducted in the dispensary with small rodents from the radioactive traces to determine radionuclide contents in organs and tissues, to estimate doses, and to study the populations of several rodent generations.

In order to provide permanent dosimetric control of the exposure levels of the inhabitants in several settlements in addition to the *in-situ* automobile gamma-survey, employees from the dispensary equipped permanent posts with dosimeter assemblies IFKU and IKS, which were replaced annually in January/February.

These activities resulted in understanding that external population exposure doses in the controlled regions for the observation period did not exceed the values stated in current Radiation Safety Standards (RSS) 76/83 for B category individuals. Intake of the biologically hazardous radionuclides strontium-90 and cesium-137 through the human food chain didn't exceed the maximum allowable annual intake even by a fraction of a percent.

Long-term observations of population health during USSR Minzdrav expeditions and in hospitals at Dispensary Number 4 have shown that the health of the people whose total long-term exposure dose

was nearly 100 rem did not differ considerably from the health of control groups. Only a small group of individuals exposed to 150-rem doses in the past demonstrated notable violations in natural immunity, cytogenetic effects, and accelerated involution processes. The surplus cancer mortality in this group was 6.6 x 10^6 cases and coincides with biological laws of the consequences of exposure in this dose range. Data are confirmed by the disease histories of the inhabitants examined in Dispensary Number 4. Children born of parents who had been exposed were clinically examined and stayed in the hospital for 7 days. They were examined by rheoencephalography, electrocardiography, spirometry, pneumotachometry, etc. Sanitary and prophylactic measures were recommended to all who were examined.

Disease histories preserved at the dispensary confirm the fact that the populations of the local settlements were poorly and improperly fed, living conditions did not meet sanitary norms, and there was almost no medical service in the settlements. The commission headed by academician A.F. Tzyb in the Semipalatinsk region in 1989 confirmed the objectivity of the data from Dispensary Number 4 on the radiation and the hygiene environments in the areas close to the test site and on the status of population health [7].

Unfortunately, there is almost no access currently to archived material at Dispensary Number 4 because after the split-up of the USSR, the dispensary was moved to another state. It is of great importance to objectively estimate the impact of nuclear tests on population health by analyzing, summarizing, and studying archived material and the results of the complex USSR Minzdrav and Minoborona expeditions in the 1950s and 1960s in the regions close to STS.

During the time of STS atmospheric nuclear tests when local radioactive traces extended into the near zone, the radiation safety control of the test participants and of the local population was based on temporary regulative documents that were valid in the USSR Minzdrav, Minoborona, and Minsredmash. These were the first documents with recommendations on radiation safety and permissible exposure doses (PED) [8–15] and led to the development and adoption in 1969 of the first USSR governmental radiation safety standards [16].

Changes in Outlook on Atmospheric Criteria and Population Radiation Safety Measures

The historic evolution in population radiation safety measures and the atmospheric criteria of the nuclear test period (1949–1962) are of great scientific interest. Their development represents a stage in the history of science in our country, particularly in radiobiology, radiation medicine, radiation hygiene, and radiation safety. The outlook on radiation safety criteria and methods changed notably with accumulated knowledge of the biological consequences of the impact of ionizing radiation on the human body.

Scientifically valid safety criteria for atomic industry personnel and the population in the Soviet Union began to develop in 1946 when the Radiation Laboratory of the USSR Academy of Medical Sciences and the Biophysical Department of the Institute of Labor Hygiene and Occupational Diseases were established. To expand research and to accelerate activities in developing standards to provide radiation safety, the Biophysics Institute of the USSR Academy of Medical Sciences was established at the Radiation Laboratory and later at the Biophysics Institute of the USSR Minzdrav (Ministry of Health). The first director of this institute was G.M. Frank, a member of the USSR Academy of Sciences; his successors were A.S. Arkhipov, A.V. Lebedinskii, P.D. Gorizontov, and L.A. Ilyin.

To resolve problems of personnel and population radiation safety, considerable contributions were made by other international institutions and national agencies, among which the leading role belongs to the International Commission for Radiological Protection (ICRP). Periodically published ICRP recommendations [17] have been used in our country since 1955 to develop national norms and rules for general population protection against ionizing radiation and radioactive substances. However, during the USSR atmospheric tests, especially at the beginning when the population living in the vicinity of the test site could have been exposed to high radiation levels, there was no governmental regulatory document nor radiation safety standards in the country. The first official radiation safety standards that regulated external and internal exposure doses for the general population and occupational personnel were adopted in the USSR in 1969 [16].

The first practical need for radiation safety measures for institute personnel as well as for the general population had already emerged in the course of research with nuclear weapons that was headed by I.V. Kurchatov, but demands for practical implementation of these measures were brought about by initial operations of the first atomic installations and by preparations for nuclear design tests at special test sites.

Even before the USSR atomic reactor E-1 was launched in December 1946 and a controlled nuclear chain reaction was attained for the first time in Europe and Asia, the State Radiation Safety Control Service had already been organized. Its first head was General-Lieutenant of the Medical Service and Deputy Minister of the USSR Minzdrav, A.I. Burnazyan (17 April 1966 to 15 October 1981) who convinced leading institutions of the Academy of Sciences and the USSR Minzdrav to develop standards and rules for handling radioactive substances as well as to design exposure control instrumentation and methods.

Nuclear weapon research and development activities were led in the USSR by the scientific-engineering council of the First Chief Agency of the Soviet Union Council of Ministers. Within this

council, consisting of distinguished scientists, Section N5 was formed for medical and sanitary control and was headed by future academicians V.V. Parin (chairman) and G.M. Frank (scientist-secretary). At the first meeting on 24 April 1946, Section N5 agreed with Ja.B. Zeldovich's proposal to organize individual photocontrol of the "radiant harm" of ionizing radiation and to fabricate dosimetry instrumentation.

Employees of the USSR Academy of Medical Sciences Radiation Laboratory designed integrating dosimeters equipped with thimble ionization chambers and photographic film. With these dosimeters they monitored the radiation environment, conducted various biological experiments with animals, and prepared for the first nuclear tests. This instrumentation was needed to estimate the destructive effect of a nuclear explosion and to enforce radiation safety measures.

The study of radiation effects on the human body and the development of all standards to regulate ionizing radiation activities were later assigned to the USSR Minzdrav Biophysics Institute [18].

The important role of supervising and arranging population and personnel radiation safety activities belonged to the Third Chief Agency of the USSR Minzdrav (currently the Federal Agency of Medical-Biological and Extreme Problems of the Russian Federation (Minzdravmedprom)), which was founded in 1954 as a result of reorganizing the Third Medical Agency. This institution was first charged with the leadership of medical service for employees of enterprises and scientific institutions in the system of the First Chief Agency of the USSR Sovmin and partially for enterprises of the Second Chief Agency of the USSR Ministry of Nonferrous Metallurgy, and later for radiation safety control of nuclear test participants and the population living close to the STS. The first head of the Third Medical Agency was A.P. Sokolov, and since February 1954 after the Third Chief Agency of USSR Minzdrav was reorganized, it was headed by A.I. Burnazyan and his deputies, P.A. Sokolov, P.P. Lyarskii, and S.Ja. Tchikin.

Thus, a separate system of medical service was organized for occupational personnel at the enterprises, scientific institutions, and organizations of the atomic industry as well as for radiation safety control for nuclear test participants and the population. This system was headed for many years by A.I. Burnazyan who was concurrently deputy minister of health for the country.

During the first nuclear weapon tests from 1949 to 1953, A.I. Burnazyan immediately took over as head of the Radiation Safety Service, the authorized representative of USSR Minzdrav, and as member of the state commission that was responsible for decisions on nuclear tests and their consequences.

Radiation safety for people living in the STS vicinity had its peculiarities because of exposure dose normalization that was not done with measured individual doses but by monitoring the amounts of radioactive substances released, their propagation and dependence on wind direction, as well as with sampling and analysis of environmental media, and with calculation techniques based on mathematical models and statistical assessments.

In the nuclear test period 1949–1958, radiation safety control of the participants and the population was based on temporary interinstitutional documentation of the USSR Minzdrav, Minsredmash, and Minoborona. These regulations contained radiation safety recommendations and permissible exposure doses.

One of the first recommendations on permissible general population exposure to ionizing radiation was developed in 1946 by G.M. Frank, A.A. Letavetov, N.O. Panasyuk, and B.G. Dubovskii, and was entitled "Tolerant Doses of Various Radiations" [19]. According to the recommended data, the PED was 0.2 R/day or 60 R/year. Based on these values, the permissible concentrations (PC) of radioactive substances in air and water were calculated, neglecting their differentiation in isotopes. Thus, the PC of beta-radiation was 2 nCi/l and for alpha radiation it was 0.01-0.1 nCi/l in air; in water, they were 1.5 mCi/l, and 10 nCi/l, respectively.

In the 1948 recommendations, PED was reduced by 2 and became 0.1 R/day or 30 R/year. In 1953, the accepted magnitude was 0.05 R and 15 R, respectively. In the years up to 1957 there were no differences in PEDs for personnel at atomic industry enterprises, for testers, nor the general population [8–12].

A turning point in the radiation safety outlook for people living in radioactively contaminated areas was developed by the USSR Minzdrav Biophysics Institute. The document was entitled "Sanitary

Rules, SR-233-57" [13], and the authors were N.Ju. Tarasenko, N.G. Gusev, A.N. Marej, and G.M. Parkhomenko. Compared with previous sanitary rules in SP-129-53 [11], these rules contained an expanded list of sanitary standards. The appendix contained PEDs for external gamma impact on the whole body: for occupational personnel, 15 rem/year; for those who did not directly operate ionizing radiation sources, 1.5 rem/year; and for the general population, external gamma doses could not be higher than the natural background dose. Thus, we can state that a difference between PEDs for occupational personnel and the general population appeared officially in the USSR in 1957. In fact, sanitary rules in SR-233-57 [13] became the basis in our country for sanitary legislation in radiation safety and were significant in resolving the problems of lowering population doses during nuclear tests in the atmosphere.

However, the most complete rules are the scientific concepts of ionizing radiation standardization presented in sanitary rules in SR-353-60 [14]. They include data on PEDs for radionuclides in water, in working room air, within sanitary zones, and especially important in inhabited settlements. These PEDs were identified differentially to account for probable exposure of three groups of human organs and their radiosensitivity. Although these sanitary rules did not account for such important factors as radionuclide migration in the food chain, they were used until 1969 in our country until the first "Radiation Safety Standards (RSS-69)" were developed [16]. The major contribution in RSS-69 development was made by the National Commission on Radiation Protection (NCRP), which was organized in the USSR Minzdrav in 1965. The well-known scientist A.A. Letavet served as its first head.

In 1976, "Radiation Safety Standards, RSS-76" was introduced to replace RSS-69 and included new scientific data on the impact of ionizing radiation on the human body and the accumulated experience with radiation control at the atomic industry enterprises and in the environment. RSS-76 provided permissible and control levels, permissible skin contamination after decontamination treatment, permissible radionuclide contents in architectural materials, etc. The values for PEDs remained unchanged.

Table 1 provides chronological changes in PEDs in different radiation environments and lists basic regulatory documents developed in the USSR. In addition to data in table 1, the recommendations in SR-353-60 [14] were accepted as starting point values in identifying PEDs for workers at the enterprises of the 4th Chief Agency, USSR Minsredmash, in 1960–1964.

Data in table 1 reveal that PEDs that essentially are applicable only to the concept of external gamma-quanta exposure (photons), were reduced constantly until atmospheric nuclear tests ceased and, in fact, from the 1960s until now have remained unchanged for both personnel and the population. With the reduced PEDs, the derived standards were becoming more demanding: permissible radioactive substance concentrations in air, permissible surface contamination, permissible radionuclide intake, and human body contents. The standards for alpha-active radionuclides (plutonium, polonium, etc.) have been made especially severe.

The draft of the Russian Federation law on radiation safety currently stipulates reduced dose limits for personnel and the population in accordance with ICRP recommendations [24].

In addition to the above, we must mention that the basic requirements of the radiation safety measures listed in the documentation were not always completely met in practice. From our point of view, to validate the need for avoiding safety standard regulations, enough arguments can always be found, especially if the political reasons are attractive.

In the course of nuclear tests many scientific studies were made in the fields of medicobiological and radiogenic consequences. Much significant data was acquired to properly organize civil defense and population/troop protection against the destructive factors of nuclear weapons. The scientific data obtained were also used in the development of additional measures to decrease exposure to the people around the STS site. Thus, in the 1961–62 nuclear test series when 69 explosions in the atmosphere were conducted, the value for external annual PEDs for the population was accepted to be 2R [25]. Moreover, to increase population radiation safety, certain constraints on the tests were introduced:

1. Radiation levels 2 hours after the explosion at the forbidden test site zone boundary (60–100 km from the test fields) had to be no higher than 0.1 R/hour, i.e., the *in-situ* dose after complete decay of radioactive substances could not exceed 1R. No more than one or two

Table 1. Permissible exposure doses (PED) for personnel and the population and main regulative dose documentation in different years.

Year and population category	Permissible exposure dose, rem		Reference	Notes
	Per day	Per year		
1946	0.2	60	19	No difference between PEDs for personnel (participating in tests) and the population.
1948	0.1	30	8	In case of an accident, a single exposure to a 25-R dose was permitted if exposure time was not less than 15 min.
1950	-	30	9	
1951	0.1	30	10,20	
1953	0.05	15	11,20	
1954	0.05	15	11,12	
1957			13	
Category A	0.05	15		
Category B	-	1.5		
Population	-	No higher than background		
1960			14	In case of an accident, a single exposure to a 25-R dose was permitted.
Category A	-	5		
Category B	-	0.5		
Population	-	0.05		
1961	-	-	15	Standards were set for contaminated food, water, air, and environment.
1969			16	For the first time a notion of "dose limit" was introduced for scheduled exposure of a certain part of the population (category A) and the population as a whole (category B).
Category A	-	5		
Category B	-	0.5		
Population	-	0.17 (5 rem for 30 years)		
1976			21,22	
Category A	-	5		
Category B	-	0.5		
1987			23	
Category A	-	5		
Category B	-	0.5		

explosions were permitted at a calculated dose rate of 0.2–0.3 R/hour at the test-site boundary with the mandatory provision that a radioactive trace would be solely in one direction (trace axis azimuth). A subsequent nuclear explosion with the wind in the same direction would not be permitted.

2. Atmospheric nuclear altitudes (h) had to be not less than 15 $\sqrt[3]{q}$ where q = explosion yield (TNT equivalent) in kilotons (kt), and h = altitude in meters; when this condition was met, nuclear tests could be done in any wind direction. However, if the wind direction was toward large inhabited settlements, e.g., cities such as Semipalatinsk or Kurchatov, then the State Commission had to seriously consider making an exception.

3. Surface nuclear explosion yield was limited to 0.5 kt (TNT equivalent). Only one explosion with a yield of 2 kt was permitted yearly and only when meteorological conditions were most favorable, wind direction was toward scarcely populated areas, and harvesting was completed.

4. Testing was forbidden in still weather when the average wind velocity was less than 10 km/hour at the 5-km-high layer, and also in the presence of atmospheric precipitation within a 100-km radius from the test field.

In the 1960s it was accepted that, if these constraints were met, radiation safety could be completely guaranteed for the population; consequently the inhabitants of areas close to the test site were not informed of the time of explosion.

The constraints listed for the test conditions and the measures for population safety were unfortunately not imposed for different reasons, and this caused radioactive contamination of the territory outside the restricted test site zone and promoted suspicion by the local population toward activity at the site.

All radioactive traces after surface and low-altitude (near surface) explosions at the STS can be divided into high, moderate, or low degrees of territory contamination. The criteria for a trace to be referred to in any group is the *in-situ* gamma-dose value until complete decay, expressed in roentgens (R).

When doses exceeded 50 R outside the test site, high *in-situ* radioactive contamination occurred after the first surface nuclear explosion on 29 August 1949 (the trace formed toward the northeast), after the second surface explosion on 24 September 1951 (the trace was toward the south), and the first thermonuclear 400-Kt explosion on 12 August 1953. This 400-Kt explosion, with a low thermonuclear factor, resulted in the highest local contamination *in situ*, and its trace was formed toward the southeast with a subsequent turn toward the east and northeast.

Moderate *in-situ* radioactive contamination at doses less than 50 R but higher than 5 R was caused by nuclear tests on 18 October 1951, 5 October 1954, 30 October 1954, 24 August 1956, and 15 January 1965. The last one, in borehole 1004 in 1965, was underground with ejecta. It was intended to create an artificial reservoir at the junction of the Chagan and Ashchi-Su rivers.

For the rest of the tests conducted at the STS, exposure doses outside the restricted test site zone were less than 5R and in general met the requirements of the regulations of the time, which stated the permissible personnel and population exposures [10–13, 20].

It is important to state that at the beginning of the STS nuclear tests (1949–1954), the major factor of harmful impact on personnel and the population was radioactive contamination of the territory. In 1955–1957, when the atmospheric tests of nuclear charges of the megaton class began, the principal harmful factor was the shock wave. Thus, in the 22 November 1955 test (1.7 Mt explosion at nearly a 2-km altitude), several accidents were recorded [26]:

> In the waiting zone (36 km from the explosion epicenter), 6 soldiers of the safeguard battalion who were in a protective shelter were buried with soil. One of them died, and the rest were injured.
>
> In settlement M.Anzhary (60 km from the epicenter), a girl died when the ceiling of the house caved in.
>
> Some inhabitants were wounded: one with a fractured thigh, two with spinal injuries, and 42 by glass debris.

After the megaton tests ceased (the last test was on 22 August 1957), and the explosion yields were restricted as stated above, the impact of the shock wave on the population was reduced considerably, and exposure doses did not exceed permissible limits.

From our point of view, the material presented here provides an idea about the changes in outlook on the standards and methods of personnel and population radiation safety that took place in the USSR during the STS nuclear test period.

Physical and Geographical Characteristics of Surveyed Territories in 1956–1958

The territory where radiological and medical examinations in 1956–1958 were done by the USSR Minzdrav and Minoborona is located in eastern Kazakhstan. This territory, almost 80,000 square kilometers, occupied the western part of the East Kazakhstan region, Semipalatinsk region, southern part of the Pavlodar region, and eastern part of the Karaganda region. This territory was chosen for complex population examinations because the nuclear test site was located at the meeting point of the four regions.

The test site, a steppe with rare low hillocks (100–300 m) and numerous salt lakes (3), was located at the junction of the Kazakh low hills and the Priob plateau. In the central and northern parts, the Priirtysh plains alternated with the central Kazakh low cliffs—alternating disorderly scattered hills and wavy plains. In the east, the mountainous part of the area, were the western cliffs of the Altai mountains, and in the south were the Tarbogataj, Chirgiz-Tan, and Akshtan ridges [3–5]. The basic water artery of the territory was the Irtysh river with its numerous shallow tributaries. The largest among them were the Ul'ba, Uba, and Ablaketka rivers. In the north Semipalatinsk region, the main tributary of the Irtysh river was the Char river; the Shagan, Mukur, and other rivers were very shallow and, in summer, were lost in the sands.

On the right bank of the Irtysh river and in the area in the western East Kazakhstan region, the soil was mainly chernozem (black earth). The western spurs of the central Kazakh low hills in the middle of the surveyed area were light-chestnut-colored soils, whereas to the south, toward the Chingiz-Tan ridges, they were gray earth. The soils to the north, northwest, and northeast from the spurs within the area of the Pri-Irtysh plain were predominantly dark chestnut-colored.

Vegetation on most of the territory was of a semi-arid type, with feather-grass, wild oats, desert timothy-grass, and different kinds of wormwood. The floodplains of the Irtysh river were covered with meadows, bushes, and trees. Forests could be seen only in the western part of the surveyed territory.

There were various types of steppe rodents and very rarely foxes or wolves.

The climate was sharply continental, with marked differences between summer and winter temperatures (+45° C to -50° C.)

Average precipitation in the northern and central parts of the surveyed regions was 200–300 mm annually. In the foothills, precipitation reached 100 mm per year.

It is known that natural climatic factors are closely related to the functional and protective responses of the human body as well as to behavioral motives that can in turn cause certain diseases, including psychical diseases. Moreover, the natural environment hides numerous hazardous infectious, viral, and parasitic diseases. Several kinds of insects, birds, rodents, other animals, and plants as well can be sources or carriers of these diseases.

Because a natural habitat can create specific conditions for both health preservation as well as its deterioration, severe natural climatic conditions in the Kazakhstan region could have negatively

affected the people's health. Considering these environmental factors, the additional impact of radiation could have amplified these negative effects to a certain extent.

Radiation Environments in Regions of Medical Examinations of the Population

It is known that natural climatic peculiarities in combination with social interaction, sanitary hygiene, and other factors influence each individual and a regional population as a whole. The health of the population and its morbidity/mortality rates from different diseases are affected by the factors already cited,way of living, structure and quality of food, bad habits, and psychoemotional and other factors [28]. Under the combined effect of these factors, three versions of their interactions are possible: additivity, synergism, and antagonism. Depending on the conditions of effect and design, the character of interaction of two factors can also vary [29].

Currently, a considerable danger for peoples' health is pollution of the biosphere, i.e., the contamination of air, water, and soil with different chemical compounds and radioactive substances. The principal impact on radioactive environmental contamination was caused by atmospheric nuclear weapon tests that were under way for many years in several countries of the world. STS nuclear tests resulted in radioactive contamination of off-site territories. The degree of impact of this type of contamination on the population's health depends primarily on exposure doses. With increased external and internal exposure doses of the population (effective doses), the degree of ionizing radiation impact on health increases. Consequently, attention was paid to estimating *in-situ* radioactive contamination and population exposure dose scales during the complex medical examinations.

The term "radiation environment" includes the degree and scale of radioactive contamination of the territory and environmental objects as well as possible values of population exposure doses. In the course of the complex expeditions, the radiation environment was studied in the involved territories by automobile, by gamma surveys on foot, and by analyzing various environmental samples to identify the contents of individual and total radionuclide activities. The results were also used of the STS radiation safety department's gamma surveys by plane and automobile that were obtained in different years after the nuclear tests. Much of the data was taken from scientific reports prepared by various specialists during the course of the tests.

Map 1 provides a schematic of radioactive contamination outside the STS for the entire period of nuclear testing. This map was drawn from the results of the analysis and summary of all available archived material and data on the radiation environment around the test site. The map shows that the greatest radioactive contamination took place after four surface explosions (29 August 1949, 24 September 1951, 12 August 1953, and 7 August 1962), one low-altitude atmospheric explosion (24 August 1956), and after an underground explosion with ejecta that was intended to create an artificial reservoir at the confluence of the Shagan and Ashy-Su Rivers. Basic data on these nuclear explosion parameters are presented in table 2 [30–32]. A brief description of the radioactive traces after the nuclear explosions must be presented; parameters are listed in table 2.

Table 2. Basic parameters of STS nuclear explosions after which considerable radioactive territory contamination was observed.

Explosion date	Energy yield, kt	Explosion altitude, m	Amount of produced biologically relevant radionuclides, Ci (July 1994)			Relative scales of radioactive contamination
			Strontium-90	Cesium-137	Plutonium	
8/29/49	22	30	500	140	360	22
9/24/51	38	30	900	2,550	300	13
8/12/53	400	30	22,000	29,000	280	25
8/24/56	2.7	100	900	2000	90	6.5
8/07/62	9.9	0	370	870	200	1
1/15/65*	140	-175	-	-	-	1.5

*Explosion detonated in a shaft.
Note: These relative radioactive contamination scale estimates accounted for off-site fallout products from the explosion only.

Map 2 shows the Republic of Kazakhstan and surrounding countries.

Test, 29 August 1949. Average wind velocity at the 6-km altitude was 40–60 km/hour with gusts to 75 km/hour [33–34]. Rain added significantly to the degree of radioactive *in-situ* contamination along the cloud trace of the explosion. The radioactive trace formed in a northeast direction. Off-site atmospheric and ground surveys [35] were conducted on 5–13 September 1949.

Radioactive contamination impacted part of the Novopokrovsk and Beskaragai areas in the Semipalatinsk region and several areas of the Altai district (Uglovsk, Loktevsk, Rubtzovsk, and others). The maximum dose of 224 R for complete decay of the explosion products in the open territory was recorded close to the Dolon settlement on the bank of the Irtysh River. The trace axis passed near the following settlements: Dolon, Mostki, Lokot, Veseloyarskoe, Kur'ya, and Seivvushka-Bijsk [36]. Table 3 provides the total doses of external radiation in the open territory as calculated with radiation survey data [35].

The gamma survey in the territory in December 1956 showed that the maximum radioactive contamination was observed in the area of Dolon and Kanonerka. From this area the contamination level decreased, whether approaching or moving away from the test field, testifiying to the impact of meteorological conditions on the degree of radioactive contamination. This was confirmed by theoretical calculations also.

Test, 24 September 1951. After this surface nuclear explosion, the radioactive trace formed to the south and southeast from test field P-1. The area where the gamma dose might have been higher than 1 R stretched like a band 200–250 km from

Table 3. *In-situ* gamma doses until complete decay of explosion products near the trace axis produced by the nuclear test on 29 August 1949.

Place of measurement	Dose (R)
Trace axis near Dolon	224
Dolon	201
Locot	31
Veseloyarskoe	13.5
Kur'ya	6.5
Petropavlovka	0.6
Bystryi Istok	0.3
Bijsk	0.3
Solton	0.3

the test-site boundary. The contamination zone covered Abai, Chubartaus, and Ayaguz areas in the Semipalatinsk region with Kainar, Molotov, Teskesken, and others. The maximum dose was recorded to be 110–115 R at 30 km to the northeast from Kainar [36]. Table 4 provides the gamma doses at several trace points.

Despite the fact that the TNT equivalent of this surface explosion was twice as much as that of the first nuclear explosion, the *in-situ* radioactive contamination scales were lower. After the explosion on 24 September 1951, the radioactive trace was formed under "dry" weather conditions.

Test, 12 August 1953. After the first thermonuclear test, the radioactive trace was formed to the southeast of the test field. By aerial and ground radiation survey data, the territory contaminated with a dose higher than 1 R was traced to 400 km off site. Radioactive contamination was observed in the Abai, Georgievsk (Zharminsk), and Ayaguzsk areas of Semipalatinsk oblast (the settlements of Sarzhal (central location of Telman kolkhoz), Abai, Kyzyltas, Zhurekadyr, and others. Table 5 provides data on the radioactive contamination of these settlements.

According to aerial radiation survey data, the radioactive explosion cloud divided into three parts after passing the Zajsan Lake (1,100 km from the test field): the first (upper) part moved to Kyzyl (Tuva Republic) along the former USSR boundary; the second (middle) part passed over Berezovka, Kokchetav, Shadrinsk (in the south Urals), Aralsk, and Namangan; and the third (lower) part passed over Berezovka, Karaganda, and Kounrad [36].

Considering previous surface nuclear explosions, the principal radiation safety measure for people living near the test site was chosen before the test: early evacuation from the sector of expected location of the radioactive trace.

Test, 24 August 1956. This was one of the last atmospheric nuclear weapon tests that were notably harmful to the territories close to the test site. The radioactive trace was formed to the east from test field P-5. The contamination zone covered the Novopokrovsk and Chara areas of the Semipalatinsk region as well as the Tavrichesk, Predgornensk, Nikitinsk, and Serebryansk areas of the East Kazakhstan region and included the city of Ust'-Kamenogorsk. Atmospheric precipitation made this radioactive contamination "spotty." In Isa (100 km from the epicenter), the external *in-situ* exposure dose was 15 R, in the city of Ust'-Kamenogorsk (342 km from the epicenter) the dose was 10 R, and in settlements Takhanka (364 km from the epicenter) and Bobrovka (345 km from the epicenter) the dose was 2.4 R.

Thus the above data on *in-situ* radioactive contamination scales after four nuclear tests (29 August 1949, 24 September 1951, 12 August 1953,

Table 4. *In-situ* gamma doses until complete explosion product decay in radioactive trace after nuclear test on 24 September 1951.

Point of measurement	Dose (R)
Kainar	9.0
30 km northeast of Kainar	107.0
1 km west of Sotzialdy Kazakhstan	81.0
Molotov	14.0
Teskesken	0.3
Tespakan	0.12

Table 5. *In-situ* gamma doses until complete explosion product decay in radioactive trace after the nuclear test on 12 August 1953 [36].

Point of measurement	Dose (R)
Tailan	972.0
Sarzhal	246.0
Abai	13.6
30 km east of Kyzyltas	55.0
35 km southeast of Zhurekadyr	23.0
Aigyrzhal	6.6
12 km northeast of Aksuat	1.8
40 km from Kyzyl-Kesek	0.1

and 24 August 1956) confirm data in table 1 that these four explosions contributed most to radioactive environmental contamination and consequently to the exposure doses for those living in the vicinity. Table 6 lists external and internal exposure doses for people from some settlements.

Table 6. Basic data characterizing radiation environment and population exposure doses of several settlements in Kazakhstan and the Altai district of Russia after the 1949–1958 nuclear tests at the Semipalatinsk test site [5,30,36,38].

	Population external exposure dose (cGy)	Probable exposure dose of thyroid (cGy)		Soil contamination density in 0-5 cm layer, Ci/km^2		Radionuclide contents in the human body[4]			
						Sr-90, × 10-10 Ci/kg		Cs-137, × 10-8 Ci/ body including contaminated food	
Settlement	All ages	Children	Adults	Sr-90	Cs-137	Children	Adults	Russians	Kazakhs
				Nuclear test data 08/29/49					
Dolon	130–150	8000	2000	0.34[1]	0.36[2]	3.2	2.8	1.8	-
Topolnoe	50–52	2800	700	(14%)	-	-	-	-	-
Naumovka	53	300	750	-	-	-	-	-	-
Lokot	28	1000	400	-	-	-	-	-	-
Veseloyarsk	12	780	190	-	-	-	-	-	-
				Nuclear test data 09/24/51					
Kainar	7	-	-	0.1 (65%)	-	3.8	3.9	-	5.4
				Nuclear test data 08/12/53					
Sarzhal	42[3]	-	-	1.0 (3%)	0.3	2.2	1.6	2.6	5.1
Kara-Aul (Abai)	13[3]	-	-	-	-	2.9	1.1	-	-
				Nuclear test data 08/24/56					
Ust'-Kamenogorsk	7.5	300	80	-	-	-	-	-	-

[1] Percentage of solubility of given radionuclide in 6N hydrochloric acid (HCL) in parentheses.
[2] Radionuclide contents as calculated for the time of radioactive contamination.
[3] External exposure doses for population in Sarzhal and Kara-Aul (Abai) are those measured when inhabitants returned after forced evacuation.
[4] Calculation and measurement error, 30% (for 95% probability).

Table 7. Data on gamma backgrounds in several regions (1958 measurements).

Region	Surveyed routes, linear km	Exposure dose rate, mR/hour		
		Minimum	Average	Maximum
Semipalatinsk	1,700	8	10	20
East Kazakhstan	380	8	10	12
Pavlodar	170	8	9	10
Karaganda	560	8	10	12

The most complete data were obtained in 1958 from the first series of complex radiological surveys in the contaminated areas and medical examinations of the population in 1956–1958. At the same time a great effort was made to study the gamma background in several settlements and areas. The automobile gamma-survey was done over an almost 80,000-km^2 area, using the automobile-transported self-recording roentgenometer SG-65. Table 7 provides gamma dose rates in the Semipalatinsk, East Kazakhstan, Pavlodar, and Karaganda regions.

The maximum dose rate of 250 mR/hour was recorded in the area of Ust'-Kamenogorsk. Increased gamma background was also noted in the Semipalatinsk region in the radioactive explosion trace on 12 August 1953. Thus, in the area of Kara-Aul, gamma dose rates were between 10 and 22 mR/ hour.

In addition to measuring the gamma background, environmental samples were analyzed during radiological research. Radiochemical analysis identified strontium-90 and potassium-40 in the samples of soil, vegetation, locally produced food, water from water supplies, and in the total activity of these samples as well. In addition, the radioactive content of human excretions (feces, urine) was determined as well as 24-hour activity of excretions (urine, 1.51 g; feces, 300 g).

Soil samples were x-rayed to define particle activity, size, form, and color.

Baseline results of the 1958 radiological study in the Semipalatinsk, East Kazakhstan, Pavlodar, and Karaganda regions (see map 3 for locations) are shown in table 8 and were abstracted from a copy of the original "Summary Map of Complex Expedition Results in 1958" [39]. Table 8 provides the sampling points and estimates of soil contamination; *in-situ* contamination density, radioactive substance contents in vegetation; and the average intake of radioactive substances in nanocuries per day by the majority of people living in the area. Data characterizing soil and food activity as well as intake of radioactive substances with food and water are provided below.

Table 8. Results of investigations.

Settlement	Expedition (E) or reconnaissance (R) survey	Surface contamination (nCi/kg)	Vegetation contamination (nCi/kg)	Ground contamination (nCi/m^2)	Radioactivity of food (nCi/day)
Pavlodar Oblast (15 population points)					
Maikain	R	35	100	350	-
Chernaya	R	29	57	290	-
Lebyazhe	R	29	11	290	-
Podpisk	R	23	90	230	-
Bayan-Aul	R	50	110	500	-
Alekseyevka	R	50	63	500	-
Zhosaly	R	43.7	38	432	-
Karashengel	R	31.7	14.5	917	-
Karatoye	R	27.6	46	275	-
Shoptikul	E	27	170	270	7.1
30 Years of Kazakhstan kolkhoz	E	20	130	200	9.2
Koyandy	E	52	120	520	-
Bastil	R	37	165	370	-
Yegendibulak	R	54	152	640	-
Moldary	E	25	16	250	4.6
Karaganda Oblast (11 population points)					
Koroboyesky	R	49	122	490	-
Prigorodny	R	44	88	440	-
Abai sovkhoz	R	32	200	320	4.5
Kyrgyzaya	R	46	120	460	-
Kalinin	R	43	10	430	-
Stapuna	R	53	120	530	-
Akshok	R	52	150	520	-
Narkaralinsk	R	39	210	390	-
Enbekshigiz	R	44	220	440	-
Frunze kolkhoz	R	48	380	480	-
Semipalatinsk Oblast (17 population points)					
Seminovka	R	35.7	88	357	-
Krivinsk	R	37.5	460	375	-
Greater Vladimirovka	R	39.5	51.8	395	-

Continued on next page.

Table 8.—*Continued.*

Settlement	Expedition (E) or reconnaissance (R) survey	Surface contamination (nCi/kg)	Vegetation contamination (nCi/kg)	Ground contamination (nCi/m^2)	Radioactivity of food (nCi/day)
Semipalatinsk Oblast (17 population points)					
Seminovka	R	35.7	88	357	-
Krivinsk	R	37.5	460	375	-
Greater Vladimirovka	R	39.5	51.8	395	-
Maisk	E	38	890	380	4.1
Semeyansk	R	14	-	140	-
Mostik	E	50	68	500	6.4
Dolon	E	38	77	380	5.3
Besterek	E	33	720	330	6.3
Semipalatinsk city	E	28	45	480	2.4
Zhana-Semey	E	26	56	280	2.0
Znamenka	E	51	93	610	4.1
Sarzhal (central part of Telman kolkhoz)	E	25	120	2500	57
Kaskabulak	R	31	110	370	-
Voroshilov kolkhoz	R	88	190	8600	-
Zhakanur	R	33	10	330	-
Kara-Aul	E	93	79	930	74
Chubartau	R	39.7	12	397	-
East Kazakhstan Oblast (10 population points)					
Shemonaika	R	36	130	360	2.5
Upper Verezovsny	R	37	140	370	-
Glubokoye	R	110	140	1100	1.0
Akitovka	E	16	74	1600	3.8
Ust'-Kamenogorsk city	E	67	96	670	6.0
Kirpichin factory	R	84	11	970	2.9
Ablaketka	E	26	13	2600	3.2
Samsonovka	E	81	74	810	1.23
Konaika	E	84	95	840	3.8
Peredabai sovkhoz	E	62	63	620	4.9

Note: 1 nCi = 37 Bq

In the copy of the original map there are 53 circles, with numbers indicating the contamination levels inside each sector of the circle and shading to indicate the correct exponent. These circles accompany the "population points" (term which describes each city, settlement, kolkhoz, or factory). The number of samples taken at each site was recorded in the original map but not recorded here. The original map also recorded readings along the roads, near some of the settlements, and at various other locations in the region. Most of these values are generally between 8 and 12 μR/hour except in some areas just outside the polygon boundaries where values of 14–20 R/hour were noted.

Radioactive Contamination of Food and Soil

Table 9 lists the average specific activity of soil samples taken at different depths in the settlements that were surveyed radiologically. Data show that lower layers (5–6 cm) of 20 nCi/kg activity were caused by potassium-40. As a rule, radioactive substances were routinely no deeper than 3–5 cm.

Strontium-90 was recorded in all soil samples from settlements that were analyzed radiochemically, and its average contents in the surface layer was 10 nCi/kg in the 1956 explosion trace and 86 nCi/kg in the 1953 explosion trace.

Attention was chiefly paid only to those food products that constituted the major daily ration for the local people: wheat (grain), bread, meat, milk, potatoes, vegetables, and water. Table 10 provides data on radioactive substances in the food produced in the settlements.

Data in table 10 confirm that the specific activity found mainly in milk corresponds to its potassium-40 contents (natural activity). Concentration of radioactive substances in the drinking water as well as in the water of opened reservoirs in all surveyed settlements was lower than the permissible norms adopted in the 1950s for radionuclide mixtures [40].

Table 9. Radioactive soil contamination in several Kazakhstan settlements on the basis of radiological examinations in 1958 [5].

Settlement	Specific activity in virgin lands at different depths (cm × nCi/kg)				Soil activity ratio in a 0-1-cm layer to activity in a 3–4-cm layer
	0–1	1–2	3–4	5–6	
Semipalatinsk					
Dolon	38	2.6	2.3	2.3	1.7
Besterek	33	2.2	2.2	2.1	1.5
Kara-Aul	93	4.1	2.7	2.0	3.4
Znamenka	51	1.9	2.2	2.0	2.3
Semipalatinsk	28	1.7	1.7	-	1.6
East Kazakhstan					
Ablaketka	260	-	2.3	2.3	11.3
Samsonovka	8.1	-	1.8	1.6	4.5
Ust'-Kamenogorsk	6.7	-	2.9	2.0	2.3
Shemonaikha (control)	3.6	-	2.3	1.9	1.6
Pavlodar					
Maisk	3.3	3.0	2.0	2.4	1.7
Moldary	2.5	1.8	1.3	1.4	1.9
Karaganda					
Abai sovkhoz	3.2	-	-	2.3	-
Shoptykkul (control)	2.7	1.8	1.4	1.3	1.9
30 Years of Kazakhstan kolkhoz	2.0	-	1.7	-	1.2

Note: Radioactive substances in arable lands were distributed almost uniformly in depth.

Table 10. Radioactive contamination of food products in several Kazakhstan settlements in 1958 [5].

Settlement	Specific activity of food products × nCi/kg (l)						Drinking water activity × 10^{-11} Ci/l
	Wheat (1957 harvest)	Bread	Meat	Milk	Potatoes	Vegetables	
Kara-Aul	1.5	3.4	3.6	0.8	-	-	2.0
Ablaketka	-	1.4	1.5	1.4	1.6	2.8	3.2
Samsonovka	19.0	12.0	2.1	0.9	3.6	3.2	2.5
Ust'-Kamenogorsk	-	2.4	2.5	1.4	3.0	2.9	7.0
Shemonaikha (control)	1.6	1.4	1.5	1.7	2.5	5.8	7.0
Maiskoe	-	2.0	2.2	1.7	3.0	7.1	3.8
Abai sovkhoz	36.0	2.6	3.3	1.1	5.7	10.5	3.0
Shoptykkul (control)	7.9	2.9	3.2	1.7	-	-	3.4
30 Years of Kazakhstan kolkhoz	28.0	2.6	3.8	1.1	-	-	2.0
Potassium-40 contents	3.5	1.2	2.3	1.2	3.0	2.3	

A recorded increase in the contents of radioactive substances in the meat and bones of sheep was caused by negligible contamination of pastures.

Intake of Radioactive Substances with Food and Water. For quantitative assessment of intake of radioactive substances, the population under examination was arbitrarily split into three groups: urban inhabitants, Russian rural inhabitants (Dolon, Znamenka, Samsonovka, Shemonaikha, Abai sovkhoz), and Kazakh rural inhabitants (Besterek, Kara-Aul, Shoptykkul, 30 Years of Kazakhstan kolkhoz). A daily food ration was identified as characteristic of each of these population groups and is presented in table 11.

Characteristically, the Kazakh population in the countryside rarely ate any vegetables in the mid 1950s.

Table 11. Daily ration for various population groups.

Food products	Food consumption/day (g)		
		Rural	
	Urban	Russians	Kazakhs
Bread	600	900	800
Meat	100	250	1,000
Vegetables (90-95% potatoes)	1,000	300	*
Groats	*	*	200
Milk	200	300	1,000 (koomys)
Water	2500	2,500	2,500
Fruit	50	*	Totally absent

*Almost absent.

Table 12. Settlements with maximum daily intake of radioactive substances by inhabitants.

Settlement	Radioactive substances in inhabitants/day (Ci)
Samsonovka	9.4×10^{-9}
Kara-Aul	3.2×10^{-9}
30 Years of Kazakhstan kolkhoz	5.0×10^{-9}
Besterek	3.4×10^{-9}

Reference [5] cites data on probable intake of radioactive substances with daily rations in 1959, 2 years after the notable *in-situ* contamination caused by the nuclear test on 24 August 1956. Among all examined settlements, only inhabitants of four settlements registered the maximum intake of radioactive substances. Table 12 lists the settlements and the amounts of radioactive substances taken in by the inhabitants.

Nuclear explosion product intake was compared to data from radiometric studies of human excrement (feces, urine) conducted during clinic examinations. The average contents of natural radionuclides (potassium-40) in daily urine and feces were 4.0 nCi. Data on total activity of human daily excrement and its excess over natural radionuclide contents are provided in table 13.

Data in table 13 show that the maximum total activity of human excrement was recorded for the inhabitants of the settlements listed in table 12 where the maximum daily intake of radioactive substances is noted.

Eventually a decrease in all settlements was recorded in radioactive substances in soil, vegetation, food products, water, and human excrements. Thus, for example, in Kara-Aul where the territory was contaminated with radioactive fallout after the nuclear test on 12 August 1953, the radionuclide contents from September 1956 until July 1958 were reduced in the surface soil level by 2.3 times, in grass by 6.9 times, in wheat (grains) by 6 times, and in food rations by more than 2 times.

In the surveyed settlements, the highest specific radioactive substances were recorded in the surface layer of soil if the degree of its reduction was lower than the degree of radioactive substances in vegetation, food products, and water.

To objectively assess the radiation environment's impact on human health in the settlements where the complex study was undertaken, data on the sanitary and hygienic state of these settlements and the living conditions of the inhabitants had to be analyzed.

Sanitary Status of Surveyed Areas. Twenty-two settlements with more than 310,000 inhabitants were studied in 1956–1958 (see table 14).

In almost all settlements studied, the inhabitants were involved in agriculture, principally in farming and raising stock. Production plants were usually located in regional centers and their vicinities: in Ust'-Kamenogorsk, a lead and zinc industrial complex, a military production plant, and two

Table 13. Radioactive substances in human excrement of surveyed settlements and excess over natural radionuclide contents [5].

Settlement	Total activity of daily excrement, nCi	Excess over natural radionuclide content (%)
Semipalatinsk		
Dolon	3.24	0
Znamenka	4.14	3.5
Semipalatinsk	4.17	4.2
Kara-Aul	5.86	46.5
East Kazakhstan		
Ablaketka	3.60	0
Samsonovka	4.74	18.5
Ust'-Kamenogorsk	3.47	0
Shemonaikha (control)	3.35	0
Pavlodar		
Moldary	2.64	0
Karaganda		
Sovkhoz Abai	4.88	22
Kolkhoz "30 Years of Kazakhstan"	5.98	49.5

Table 14. Study of settlements and their populations in 1956–1958 as of 1 January 1958.

N	Region and settlement	Population
	Semipalatinsk region	
1.	Semipalatinsk city	145,510
2.	Zhana–Semey	(Included in 1 above)
3.	Telman kolkhoz*	633
4	Znamenka	832
5.	Abai (Kara-Aul)*	2,296
6.	Dolon	1,228
7.	Mostik	538
8.	Besterek	123
	East Kazakhstan region	
9.	Ust'-Kamenogorsk	126,000
10.	Ablaketka	11,822
11.	Samsonovka	300
12.	Zavety Ilicha sovkhoz	300
13.	Settlement around a brick production plant	300 max.
14.	Shemonaikha	15,596
15.	Kanaika	300
16.	Peredovoy sovkhoz	300 max.
	Pavlodar region	
17.	Maisk	2,214
18.	Moldary	1,200
	Karaganda region	
19.	30 Years of Kazakhstan kolkhoz	133
20.	Abai sovkhoz	676
21.	Shoptikkul*	189
22.	Koyandy*	15
Total		310,595

*Settlements inhabitated mainly by Kazakhs; the rest were inhabited by Russians, Ukrainians, and others.

woodworking complexes were operating; in the Ablaketka/Ust'-Kamenogorsk power station, a capacitor production plant was under construction; in Semipalatinsk, a large meat processing and packing factory is still operating, and a cement production plant was built and is currently in operation.

The analysis of complex study materials supports the statement that the sanitary environment in both the cities and the countryside did not meet elementary hygienic norms. It is known that human health is directly related to sufficient amounts of high quality water. The water supply for the surveyed settlements was totally unsatisfactory.

In the 1950s in the Semipalatinsk region, 11 water pipes were functioning, 6 of them in Semipalatinsk. However, the basic sources of water for Semipalatinsk inhabitants were springs coming to the surface. The water almost satisfied the requirements of GOST-54 in chemical and biological indices. In the summertime however, the citizens had to take water from the Irtysh and Semipalatinka rivers. Chemical and bacteriological analysis of water from these rivers revealed its high contamination with sewage (oxidizability, 32.3 mg/l; ammonia contents, 0.14 mg/l; and suspended substances, 24 mg/l). The rivers were contaminated by two then-operational sewer collectors, one municipal and the other from a meat processing and packing factory that did not have required cleaning facilities and consequently drained the water directly into the river. Also, without any disposal of wastes, 38 industrial plants in the city drained their water directly into the Irtysh river. This contamination of the reservoirs impacted negatively on their biological state and was one of the causes of the increasing rate of sickness from intestinal infections among the people living on the river banks [4,5].

In the settlements of the East Kazakhztan region, water was supplied by wells and open reservoirs—lakes, rivers, and springs. In the regional center, Ust'-Kamenogorsk, there was no municipal water pipe; its construction hadn't yet started in 1953. The city was supplied with water by 19 local water pipes that provided only 40% of the citizens with water. The principal sources of water were individual wells, boreholes 8–25 m deep, and the Irtysh and Ulba rivers whose waters had unsatisfactory chemical and bacteriological indices. The rivers were contaminated mainly by drainage of household fecal waste and industrial sewage.

The operating water pipes in Ust'-Kamenogorsk were not completely equipped with cleaning facilities; only 9 of 19 water pipes were equipped with chlorination capability. It should be noted that permanent water chlorination was available only in Ablaketka where the water was supplied from the bank of the bed under the Irtysh river.

The chemical indices on the drinking water from the pipes in Ust'-Kamenogorsk and its vicinity showed lower transparency (17–25 cm), higher turbidity (36–53 mg/l), oxidatibility, hardness, as well as higher contents of ammonia nitrites and nitrates (3–36 mg/l). Bacteriological water indices that had to meet GOST-54 requirements were permanently kept in compliance in only 6 water pipes of Ust'-Kamenogorsk, and variations in the coliform titer from 50 to 200 were recorded in the rest, especially in the spring and summer. In the public wells of the city and the rural settlements of the region, the water had a 0.1–10 coliform titer, and in the spring and summer months less than 0.1 in the free-standing wells.

In the majority of rural settlements in both the Semipalatinsk and East Kazakhstan regions, water that came from springs, small rivers, and individual/public wells was extremely unsatisfactory. Wells rarely met sanitary requirements. Water quality was never controlled by laboratory analysis in the regional areas.

The quality of water was bad in the wells of the Pavlodar and Karaganda regions also [5]. Laboratory analysis of water quality was not done for the reservoirs of these regions either.

In the regional centers of Semipalatinsk and Ust'-Kamenogorsk, severe contamination of the atmosphere from electric heating plants and various industrial enterprises was observed. According to the Sanitary Epidemiological Station (SES) of these cities, the contents of chemical substances in the atmosphere greatly exceeded the maximum permissible concentrations: for example, lead, by 31–300 times; arsenic, by 2–5 times; and sulfur dioxide, by 3–66 times.

The cities and settlements of all four regions had few paved asphalt streets, few trees, and little grass, which resulted in highly dusty environments. There was almost no washing or cleaning of streets, which were also contaminated with domestic wastewater.

Information about unsatisfactory sanitation in rural settlements attracts attention. In the countryside there were no bathing facilities, public utilities, regular clearing of places where household waste accumulated, and no pure water because the wells were practically never cleaned. Furthermore, the quality of food was poor, and the people ate substances not fit for nourishment.

A diet must be good in composition, quality, and calories to preserve good health and is a dominant factor in the evolution of some diseases of the digestive, cardiovascular, and urogenital systems, congenital anomalies, blood diseases, and others [27]. The examination revealed that the diets of both urban and rural populations were inferior, monotonous, and basically consisted of bread, meat, milk, and cookies.

Practically no vegetables or fruits were available, and 90% of the vegetables were potatoes. Table 11 shows a typical daily ration of food for urban and rural populations. This ration points to the insufficiency or almost full absence of vegetables and fruits, especially among the Kazakhs. The locals did not have vegetables or fruits because there were no gardens nor personal orchards, and the climate was too severe.

Foodstuffs were not regularly delivered, especially in rural regions, and the amount delivered was less than it should have been. According to existing ration scales in 1956–1958, the inhabitants should have been supplied with 30,000 tons of meat per year, but only 2,466 tons were provided in 1958; 134,000 tons of milk, but only 17,200 tons were provided, and 37,000 tons of fruit, but only 250 tons were provided. The limits on fats, fish, vegetables, sweets, cookies, and other products were insignificant.

We must state that for the whole country the 1950s were years of national economic recovery after the severe and exhausting war of 1941–1945. Many unsatisfactory living and household conditions can be attributed to the hardships of that time. However, we must admit that even now the sanitary environments in the regions under study leave much to be desired. This is confirmed by the results obtained by the expert team headed by academician A.F. Tzyb in May 1989 in the Semipalatinsk region [7]. This team noted in its report that "there is no sewer system operating in all rural areas. As a result of the economic activities of the sovkhozes there is general contamination of small rivers and the Irtysh river. Cases were discovered where cattle farm

stalls had not been cleaned since 1986. Chemical weed and pest killers are stored carelessly. In 95% of the buildings used for these purposes, only a third of the stores is surrounded by a protection zone. There is no appropriate accounting of chemical weed or pest killers, some of which have been in storage since 1982–1983. Inevitably, this causes contamination of reservoirs, soils, and forage. Doses of pesticides higher than the permissible concentration limits get into food products. . . .The standard diet does not correspond to the concepts of optimal nutrition and is characterized by an evident lack of products of animal origin and of garden orchard products with the excessive consumption of flour and grain products. . . ." [7].

Thus the analyses of the complex study of the inhabited settlements where territories were contaminated with radioactive substances in different years after nuclear weapon tests at the Semipalatinsk test site, have shown that the living conditions of the inhabitants of the settlements, particularly the sanitary, hygienic, and social conditions, did not meet sanitary norms. Insufficient public services and utilities in the cities and especially in the countryside, lack of regular clearing, almost complete absence of sewer systems, drinking water of low quality, unfit food substances, and a monotonous diet were the causes of high sickness rates from gastrointestinal and other chronic infections, tuberculosis, brucellosis, syphilis, gonorrhoea, trachoma, etc. The Semipalatinsk region's SES employees admitted that almost 45% of the inhabitants were ill with brucellosis in the studied areas. Following data attest to the high rate of infectious diseases.

Characteristics of General Sickness in the Semipalatinsk and East Kazakhstan Populations

The expedition doctors noted in the clinical examinations of the population that the majority of those who lived in the contaminated areas complained of symptoms relating to the gastrointestinal tract. The results of data from the study that characterized the index of the general sickness rate have shown that in the Semipalatinsk and East Kazakhstan regions the highest sickness rate was for intestinal infections: dyspepsia, enteritis, colitis, acute dysentery, etc. Medical researchers considered this the consequence of poor sanitary conditions, consumption of water not fit to drink, and monotonous and inadequate nutrition, as well as unsatisfactory medical service. Table 15 presents information on infectious diseases in the Semipalatinsk and East Kazakhstan regions in 1955–1957.

Table 15. Sickness rates for Semipalatinsk and East Kazakhstan regions, 1955–1957 (regional SES data).

	Sickness cases in different years/10,000 men					
	Semipalatinsk			East Kazakhstan		
Disease	1955	1956	1957	1955	1956	1957
Acute dysentery	88.0	61.0	71.0	131.3	73.9	70.7
Typhoid fever	-	4.3	2.8	3.0	3.2	3.8
Paratyphus	-	1.2	1.0	-	0.4	0.5
Dyspepsia, simple	82.0	65.0	82.2	-	52.2	47.6
Dyspepsia, toxic	7.4	6.5	5.8	-	9.7	7.7
Enteritis and colitis	85.0	81.0	96.0	-	53.3	54.0
Typhus	-	-	0.1	0.15	0.2	0.3
Diphtheria	6.2	12.3	14.4	-	13.0	9.6
Scarlet fever	39.6	16.5	10.4	-	44.6	23.0
Measles	88.0	52.6	63.4	-	72.6	128.9
Hepatitis, epidemic	-	16.5	12.1	-	15.6	15.8
Whooping cough	-	42.4	14.7	-	43.8	50.6
Poliomyelitis	-	0.3	1.2	-	0.28	1.2
Angina	-	-	286.0	-	-	306.5
Viral grippe	-	-	769.0	-	-	591.5
Catarrh	-	-	676.0	-	-	665.9

Note: Dashes indicate that no data are available because there was almost no medical registration nor documentation until 1956.

Data in table 15 confirm that the most frequent diseases in both regions were viral diseases (catarrh, influenza, angina, measles, and scarlet fever, and in the gastrointestinal tract, dysentery, enteritis, and colitis). The decrease in the acute dysentery rate in 1956–1957 draws attention to partial improvement in sanitation in some contaminated settlements, improved diagnoses, and improved treatment of chronic dysentery after the first 1956 USSR Minzdrav expedition when specialists noted that, in addition to the unsatisfactory activity of the local health service, there was almost a complete absence of medical accounting and documention, especially in the countryside. Therefore, from our point of view, the indices of the sickness rate might have been higher than those presented in official documents.

In addition to the infectious diseases listed in table 15, there were high sickness rates for tuberculosis, brucellosis, trachoma, and venereal diseases (syphilis and gonorrhea). Data on the number of people with these diseases and those who were taken into medical institutions in 1957 in both regions are provided in table 16.

These diseases are known to induce changes in human organs and systems and are also characteristic of exposure to low-dose ionizing radiation. The differential diagnosis was therefore impeded from the beginning.

Attention was paid during examinations to the indices characterizing cancer, nervous diseases, stillbirths, and abnormalities of development. Thus, in the Semipalatinsk region, a small increase in cancers in 1957 was recorded in comparison with 1955 and 1956, and in the East Kazakhstan region a decrease was recorded in 1957 compared with 1955–1956 but more than a twofold increase in comparison to 1952 (see table 17).

Specialists have explained the recorded increase in the cancer rate as the result of better documentation and the increased knowledge of medical people in identifying the sick. The most frequent neoplasm by site in both regions was skin cancer, followed by uterine cancer, intraoral cancer (most often the lip), and stomach cancer. The high rate of skin cancer is attributed by local oncologists to climatic and meteorological conditions endemic to those regions: frequent daytime winds, lots of sunshine, marked continental climate, etc., and in the cities, the impact of harmful industrial wastes as well. Oncological diseases were recorded principally in people 40–60 years old.

According to reported data there was no increased sickness rate recorded for nervous system disorders during 1955–1957.

In general, the indexes of stillbirth for each region were not above the average stillbirth index for the Soviet Union, and in different years they were from 2.4% to 15%. No increase in congenital anomalies was recorded, particularly in hydrocephalus, cleft palate, and lip. There was an observed 10%–12% decrease in neonatal mortality during the first year of life in 1955–1957.

Lack of statistical accounts and data about blood diseases for these years prevented establishing the population sickness rate for this index.

Thus, the analysis of general sickness for the Semipalatinsk and East Kazakhstan region inhabitants proves that the changes recorded in 1956–1958 in the indexes characterizing the health of the population of these two regions cannot be totally related to the activity at the STS. This observation is especially valid for the data on increased cancer cases in the East Kazakhstan region contaminated in 1956, because the increase in oncological diseases had been observed much earlier (table 17). Considerable attention was paid in this work to the analysis of the clinical-hematological examination results of the population in some settlements of these two regions that were obtained in 1956–1958.

Table 16. Number of men with tuberculosis, brucellosis, trachoma, and venereal diseases in the regions of Semipalatinsk and East Kazakhstan (SES data), 1957.

Region	Tuberculosis	Brucellosis	Trachoma	Syphilis	Gonorrhea
Semipalatinsk	2,332	1,346	229	75	1,127
East Kazakhstan	2,298	1,454	331	190	1,696

Table 17. Cancer patients (men) in Semipalatinsk and East Kazakhstan Regions, 1952–1957.

	Men with malignant tumors					
Region	1952	1953	1954	1955	1956	1957
Semipalatinsk	-	-	-	941	935	1,054
East Kazakhstan	835	1,200	1,141	2,292	1,986	1,876

Source: Cancer Clinical Center. Data include only those who were on the registries of the cancer clinics.

Clinical Hematological Study and Analysis of Inhabitants Contaminated with Radioactive Substances

Four settlements in the Semipalatinsk region (city of Semipalatinsk, settlements Znamenka, Kara-Aul , and kolkhoz "Thalman") and six settlements of the East Kazakhstan region (city of Ust'-Kamenogorsk, and settlements Ablaketka, Kanayka, Samsonovka, sovkhoz "Peredovoy," and kolkhoz "Zavety Ilicha") were chosen for the study. Shemonaikha in the East Kazakhstan region was chosen as a control settlement because it had not been subject to radioactive contamination prior to the time of examination and was similar in climatic and physical geographic conditions, occupations, dietary patterns, and living conditions to the settlements that were contaminated by radioactive substances.

Basic Approaches to Choosing Individuals for Clinical Hematological Examinations

To examine all inhabitants in each settlement was practically impossible; therefore, expedition doctors selected or accepted individuals for clinical hematological examinations according to the following criteria:

- Dairy farm and collective farm workers, teachers, students, etc.
- Individuals with infectious diseases and other pronounced illnesses that could mask specific changes in their health that might have been due to radiation exposure.
- Inhabitants who on their own initiative consulted expedition doctors for clinical examinations and for medical service in general.
- Individuals who had earlier displayed some functional deviations characteristic of radiation sickness and practically healthy people with no pathological deviations were repeatedly examined as well.

Examining individuals for a second time was very difficult because some had moved, and some did not respond to requests for follow-up examinations because of agricultural activities.

A scheme for the examinations was adopted from the practice of clinical studies of radiochemical industry workers that included therapeutic, neurological, and dermatological examinations [41]. A hematological assay determined the quantity of erythrocytes, hemoglobin (by the old scale), reticulocytes, leukocytes, thrombocytes, erythrocyte sedimentation rate, as well as estimating differential blood composition by a dry stained smear. Standard indices of the peripheral blood were considered to be the blood indices of a practically healthy man (table 18).

Additionally, in the 1958 examination of the people the functional state of taste and olfactory analyzers, vibrational sensitivity, as well as oculocardiac and epigastric reflexes that characterize the activity of the vegetative-vascular system were studied.

To evaluate the health status of the population in the most contaminated areas, medical examinations of a number of inhabitants were conducted. Among them, individuals were excluded who had infectious and somatic diseases (brucellosis, decompensated heart failure, etc.), and for further clinical-hematological study practically healthy people were examined as well as individuals with illnesses that could have been caused by

Table 18. Peripheral blood indices of a healthy man (standard indices in literature).

	Peripheral blood index values			
Peripheral blood indices	Male	Female	All adults	Children 8–14 years old
Erythrocytes, millions/mm^3	4.1–4.9	3.8–4.6	-	4.19–5.36
Hemoglobin, Sali units	80–108	70–95	-	80–92
Color index			0.8–10	0.85–0.95
Reticulocytes (%)			4–12	4–10
Thrombocytes			200–300	200–300
Erythrocyte sedimentation rate, mm/h	6–10	6–15		4–10
Leukocytes, thousands/mm^3			5–8	6.1–11.3
Neutrophils				
Stab (%)			1–7	1–7
Relative (%)			47–75	48–57
Absolute, thousands			2.7–5.3	4.0–4.8
Lymphocytes				
Relative amount (%)			19–33	27–41
Absolute amount, thousands			1.3–2.1	2.2–3.0
Eosinophils (%)			1–5	2–4
Monocytes (%)			4–8	6–9
Clotting time (min) (Mas and Magro)			8–12	8–12
Bleeding time (min) (Duke)			up to 3	up to 3
Osmotic resistance of erythrocytes				
Minimum			0.36–0.28	
Maximum			0.50–0.46	
Clot retraction index			0.3–0.5	

the effects of radioactive substances (chronic gastritis, bronchitis, or tonsilitis). Individuals who were sick with both early and compensated forms of general diseases, functional neurovascular diseases, as well as with diseases that do not notably influence the peripheral blood contents (slight signs of interstitial emphysema, compensated heart trouble, residual signs of pleurisy, angina pectoris and others) were not excluded. This approach in choosing people to be studied clinically/hematologically was applied in all contaminated settlements.

Analysis of Results of Population Clinical Examination Data. In 1958 in the contaminated settlements of Semipalatinsk and East Kazakhstan regions, 778 inhabitants were examined by expedition doctors, and 131 of them were chosen for further study. In 1957, 619 inhabitants were examined, and 159 of them were chosen for further study. In 1958, only 194 of the 800 individuals examined were suggested for clinical hematological study. Table 19 summarizes the data (in percent) by sex, age, profession, and nationality of the examined inhabitants of the settlements in these two regions; it

Table 19. Sex, age, profession, and nationality of the examined inhabitants in the contaminated settlements of Semipalatinsk and East Kazakhstan regions and the control settlement of Shemonaikha [3–5].

Sex, age, profession, and nationality	Relation to total number examined (%)		
	Semipalatinsk region	East Kazakhstan region	Settlement Shemonaikha
Total	100	100	100
Sex: Men	63	41	51
Women	37	59	49
Age (years)			
11–20	11	11	27
21–30	39	42	18
31–40	24	31	39
41–50	20	10	12
51 and older	6	6	4
Profession			
Agriculture workers	24	12	-
Machine operators	3	9	10
Workers	3	16	37
Office workers	60	58	25
Students	7.5	1.5	27
Housewives	2.5	3.5	1
Nationality			
Russian	31	65	78
Kazakh	52	13	-
Ukrainian	8	9	7.5
Belorussian	-	7	1.5
Other	9	6	13

also shows that mainly people of able-bodied age (60%–70%) were chosen. In the East Kazakhstan region, more women than men were examined.

Among the working population, more office workers than other workers were examined. In the Semipalatinsk region settlements the majority among the examined were ethnic Kazakhs; in the East Kazakhstan region, they were Russians.

To evaluate the health status of the inhabitants of the contaminated settlements it was reasonable to compare data on the number of general diseases of the local population in 1956, 1957, and 1958, including only those who were examined twice.

In the East Kazakhstan region, 25 persons were examined in 1956, 50 in 1957, and 127 in 1958. In the Semipalatinsk region 12 persons were examined in 1956, 26 in 1957, and 67 in 1958. Table 20 presents data characterizing the rate of pathological symptoms in 1956–58 for the inhabitants of both regions where complex medical expeditions were conducted.

Table 20 presents data in the Semipalatinsk and East Kazakhstan regions in 1956 when examined

Table 20. Basic pathological symptom frequency in inhabitants in surveyed settlements in the Semipalatinsk and East Kazakhstan regions and in the control settlement of Shemonaikha, 1956–1958 [3-5].

	Symptom frequency in different years of medical study (number (N) and percent (%))					
	Semipalatinsk region					
	1956		1957		1958	
	N	%	N	%	N	%
Symptoms	12	100	26	100	67	100
Depressed appetite	1	8	4	15	10	16.0
Belching	-	-	1	4	4	6.4
Heartburn	-	-	1	4	5	8.0
Nausea	-	-	-	-	5	8.0
Vomiting	-	-	-	-	2	3.2
Pain in stomach	1	8	3	11	11	17.0
Pain in liver	-	-	-	-	4	6.4
Pain in bones and joints	5	42	10	38	17	27.0
Pain in heart	1	8	1	4	8	13.0
Short breath under light physical load	1	8	1	4	6	9.5
Indistinct heart tones	1	8	5	19	18	28.0
Tachycardia	4	33	3	11	16	28.0
Low systolic pressure	1	8	10	38	16	28.0
Low diastolic pressure	-	-	15	58	14	28.0
Reduced pulse pressure	-	-	-	-	-	-
Spontaneous hemorrhage	-	-	-	-	-	-
Positive symptom of "a pinch"	-	-	1	4	3	4.8
Cough	-	-	1	4	6	9.5
Wheeze in lungs	-	-	-	-	2	3.2
Patch on tongue	1	8	-	-	10	16.0
Enlarged and friable tonsils	2	16	4	15	9	14.0
Bleeding gums	-	-	3	11	3	4.8
Bleeding from the nose	-	-	-	-	3	4.8
Enlarged thyroid	-	-	1	4	-	-
Enlarged liver	-	-	-	-	1	1.6

Continued on next page.

Table 20—*Continued.*

	Symptom frequency in different years of medical study (number (N) and percent (%))							
	East Kazakhstan region						Shemonaikha	
	1956		1957		1958		1958	
	N	%	N	%	N	%	N	%
Symptoms	25	100	50	100	127	100	67	100
Depressed appetite	3	12	12	24	33	26.0	4	6.0
Belching	-	-	3	6	7	5.5	2	3.0
Heartburn	1	4	4	8	10	8.0	2	3.0
Nausea	2	8	3	6	10	8.0	2	3.0
Vomiting	-	-	3	6	2	1.6	1	1.5
Pain in stomach	-	-	10	20	18	14.0	3	4.5
Pain in liver	3	12	5	10	14	11.0	3	4.5
Pain in bones and joints	6	24	16	32	35	27.0	14	21.0
Pain in heart	-	-	5	10	11	8.7	3	4.5
Short breath under light physical load	5	20	9	18	12	9.5	3	4.5
Indistinct heart tones	5	20	19	38	26	20.0	16	24.0
Tachycardia	8	32	12	24	17	13.4	16	24.0
Low systolic pressure	10	40	7	14	61	48.0	18	27.0
Low diastolic pressure	11	44	10	20	56	44.0	14	21.0
Reduced pulse pressure	1	4	-	-	8	6.3	1	1.5
Spontaneous hemorrhage	1	4	-	-	3	2.4	-	-
Positive symptom of "a pinch"	3	12	5	10	13	10.2	1	1.5
Cough	-	-	5	10	6	4.8	2	3.0
Wheeze in lungs	1	4	3	6	4	3.2	-	-
Patch on tongue	-	-	2	4	18	14.0	7	10.0
Enlarged and friable tonsils	1	4	8	16	19	15.0	8	12.0
Bleeding gums	1	4	6	12	16	12.6	7	10.0
Bleeding from the nose	-	-	1	2	4	3.2	-	-
Enlarged thyroid	11	44	16	32	34	27.0	12	18.0
Enlarged liver	1	4	3	6	5	4.0	1	1.5

inhabitants displayed fewer symptoms than in 1957 and 1958. The explanation for the increased cases of pathological symptom origin after 1956 is presented in table 21, which shows data that characterize quantitatively the diseases observed in the examined inhabitants of the contaminated settlements.

Table 21. Quantitative characteristics of diseases observed in inhabitants of surveyed settlements in Semipalatinsk and East Kazakhstan regions and in the control settlement of Shemonaikha.

	Cases diagnosed in different years by locality, number (N), and percentage (%)					
	Semipalatinsk region					
	1956		1957		1958	
	N	%	N	%	N	%
Diseases	12	100	26	100	67	100
Rheumatism	-	-	-	-	1	1.5
Compensated heart desease	1	8.3	-	-	-	-
First degree hypertension	-	-	-	-	1	1.5
Myocardiodystrophy and cardiosclerosis	-	-	-	-	2	3.0
Stenocardia (angina pectoris)	-	-	-	-	2	3.0
Chronic bronchitis	-	-	-	-	2	3.0
Emphysema	-	-	-	-	1	1.5
Pleurisy (residual signs)	-	-	-	-	-	-
Chronic gastritis	-	-	1	3.9	6	9.0
Chronic enteritis	-	-	-	-	-	-
Chronic cholecystitis	-	-	-	-	-	-
Chronic hepacholecystitis	-	-	-	-	1	1.5
Chronic tonsilitis	3	25.0	2	7.7	3	4.5
Hyperthyroidism	-	-	-	-	-	-
Arthritis and polyarthritis	-	-	-	-	-	-
Chronic adnexitis	-	-	-	-	4	6.0
Dermatitis (nonspecific)	-	-	-	-	1	1.5
Eczema	-	-	-	-	3	4.5
Dermatomicosis	-	-	-	-	-	-
Ulcer diseases	-	-	-	-	6	9.0
Other	1	8.3	2	7.7	3	4.5
No abnormalities discovered	7	58.3	20	76.9	41	61.2

Continued on next page.

Table 21 shows that most of the pathological symptoms in table 20 are explained by common diseases that were revealed in repeated examinations. Data in table 21 show a slight increase in pathological symptoms in the gastrointestinal tract and in the number of chronic gastritis cases in the inhabitants of the contaminated areas when compared to controls.

Table 21—*Continued.*

	Cases diagnosed in different years by locality, number (N), and percentage (%)							
	East Kazakhstan region						Shemonaikha (control)	
	1956		1957		1958		1958	
Diseases	N 25	% 100	N 50	% 100	N 127	% 100	N 67	% 100
Rheumatism	-	-	-	-	3	2.3	1	1.5
Compensated heart desease	1	4.0	1	2.0	2	1.6	-	-
First degree hypertension	-	-	1	2.0	1	0.8	-	-
Myocardiodystrophy and cardiosclerosis	-	-	1	2.0	2	1.6	6	9.0
Stenocardia (angina pectoris)	-	-	-	-	2	1.6	-	-
Chronic bronchitis	1	4.0	1	2.0	2	1.6	1	1.5
Emphysema	-	-	1	2.0	1	0.8	-	-
Pleurisy (residual signs)	-	-	-	-	1	0.9	-	-
Chronic gastritis	-	-	5	10.0	13	10.1	1	1.5
Chronic enteritis	-	-	-	-	2	1.6	-	-
Chronic cholecystitis	1	4.0	1	2.0	6	4.7	2	3.0
Chronic hepacholecystitis	2	8.0	2	4.0	3	2.3	-	-
Chronic tonsilitis	3	-	1	2.0	10	7.9	4	6.0
Hyperthyroidism	-	-	-	-	6	4.7	2	3.0
Arthritis and polyarthritis	-	-	1	2.0	6	4.7	1	1.5
Chronic adnexitis	-	-	-	-	16	12.5	4	6.0
Dermatitis (nonspecific)	-	-	-	-	3	2.3	1	1.5
Eczema	-	-	-	-	2	1.6	3	4.5
Dermatomicosis	-	-	-	-	2	1.6	2	3.5
Ulcer diseases	-	-	-	-	6	4.7	1	1.5
Other	-	-	1	2.0	-	-	-	-
No abnormalities discovered	20	80.0	33	66.0	73	57.5	50	74.5

The repeated medical examinations of inhabitants of the Semipalatinsk and East Kazakhstan regions allowed us to determine that some observed deviations in the health of these inhabitants were signs of latent and atypical forms of brucellosis or initial signs of somatic diseases.

In 1958, a gynecologist examined women in the contaminated areas for the first time and diagnosed a great number of gynecological diseases: vulvovaginitis, trichomoniasis, cervical erosion, and others.

In 1957 in outpatient and inpatient examinations (Dispensary Number 4), some individuals in both regions displayed symptoms characteristic of radiation pathology. However, the 1958 examination of these people revealed that the earlier observed symptoms were from infectious or somatic diseases unrelated to the radiation effect. Therefore, it cannot be denied that the cause of the enhanced expression of separate symptoms might have been from the radiation factor. In this case we must note that the causes of acute or chronic radiation sickness were not recorded in any examined settlement, and the observed insignificant functional changes can be considered as physiological responses to comparatively low doses of external and internal exposures.

In the course of examinations, certain complaints and objective symptoms indicated changes in the nervous system: headaches, dizziness, weakness in general, fatigue, uneasy sleeping, and excessive perspiration. Each of these symptoms was more frequent among the inhabitants of the Semipalatinsk region settlements.

The observed cases of neurasthenia and nervous peripheral system diseases were characterized by similar rates in both contaminated and control settlements.

With each year, complaints of previous symptoms decreased; however, there were no significant trends in objective neurological symptoms observed, except for tremor of the hands and fingers and red dermographism.

Of interest are the data on the observed asthenic state and vegetovascular dysfunction of unclear etymology. There were suppositions that these changes were coupled with the radiation impact. Data from the literature indicate these changes are characteristic of individuals working with ionizing radiation. However, asthenic states of unclear etiology were observed in only a few cases, and the vegetovascular dysfunction of unclear etiology was recorded more frequently in the control settlement. This causes doubts that the changes were induced by radiation-related factors.

The results of repeated examinations of inhabitants in the contaminated areas confirm that there were no notable changes in their nervous systems.

Examination results that were compared show that most clinical indices with changes observed in 1956 and 1957 were normal in 1958.

The most valuable indices characterizing the health status of man are those of the peripheral blood, the analysis of which is provided below.

Results of Analysis of Hematological Examination Data

Analysis and comparison of the results of hematological examinations of the population in contaminated areas have shown that instability of peripheral blood indices was recorded during the period 1956–1958. As noted, normal values are considered to be the peripheral blood indices of a healthy man (table 18). The range of standard blood cell contents was determined annually for each settlement and for the region as a whole.

Tables 22-28 present the results of the examinations and show that peripheral blood indices for the inhabitants of the Semipalatinsk and East Kazakhstan regions in 1958 did not reveal great differences when compared with data for the control settlement of Shemonaikha. A higher number of reticulocytes and moderate thrombocytopenia were noted in the Semipalatinsk region than in the control settlement.

In 1956, the inhabitants of the East Kazakhstan settlements showed an increase in erythropoiesis with a higher percentage of reticulocytes than in the control of 1958 (10.7% versus 1.0%) and almost 3 times fewer cases of reticulopenia (9.5% versus 27.0%; table 27); this number in 1957 increased to 52.4%. In 1956 considerably more people in the

contaminated settlements revealed increased hemoglobin content in comparison to control (61.9%–68.0% versus 42.6–43.2% in control; table 22), and in 1957 the number of individuals with higher hemoglobin contents was even higher (83.4% for women and 73.3% for men).

Table 22. Indicators of erythropoietic function in contaminated regions and the control settlement, 1956–1958.

Region/settlement	Year	Percent of individuals of different ages with erythrocytes					
		Normal		Above normal		Below normal	
		Male	Female	Male	Female	Male	Female
		Erythrocytes					
Semipalatinsk	1956	68.9	66.0	25.5	25.0	5.6	9.0
	1957	43.0	54.8	39.2	22.2	17.8	23.0
	1958	45.7	57.1	42.8	42.9	11.4	-
East Kazakhstan	1956	53.6	57.0	46.4	37.5	-	5.5
	1957	83.3	71.2	13.9	24.4	2.8	4.4
	1958	63.0	80.0	35.2	15.7	1.8	4.3
Shemonaikha (control)	1958	55.4	61.5	42.6	34.0	2.0	4.5
		Hemoglobin					
Semipalatinsk	1956	48.0	54.0	41.4	26.0	10.6	24.0
	1957	44.8	63.9	35.1	23.3	20.1	12.9
	1958	17.6	42.9	82.3	57.1	-	-
East Kazakhstan	1956	32.0	38.1	68.0	61.9	-	-
	1957	16.6	26.7	83.4	73.3	-	-
	1958	60.0	62.3	30.0	31.3	10.0	6.6
Shemonaikha (control)	1958	57.4	56.8	42.6	43.2	-	-
		Reticulocytes (for both sexes)					
Semipalatinsk	1956	76.0		1.7		22.3	
	1957	68.5		2.5		29.0	
	1958	61.1		12.9		25.9	
East Kazakhstan	1956	79.8		10.7		9.5	
	1957	46.0		1.6		52.4	
	1958	68.0		3.2		28.8	
Shemonaikha (control)	1958	72.0		1.0		27.0	

Table 23. Erythrocyte and hemoglobin contents in blood of inhabitants examined in Semipalatinsk and East Kazakhstan regions and control settlement of Shemonaikha.

		Erythrocyte contents in blood of examined inhabitants of both sexes (mln/cub.mm^3)							
		Average		Minimal		Maximal		Zone of a wide norm	
Region/settlement	Year	M	F	M	F	M	F	M	F
Semipalatinsk	1956	4.7	4.4	4.0	3.2	5.6	5.4	4.45–4.95	4.05–4.75
	1957	4.8	4.2	3.4	2.9	6.2	6.0	4.35–5.25	3.80–4.60
	1958	4.8	4.6	4.0	3.9	6.2	5.2	4.45–5.15	4.25–4.95
East Kazakhstan	1956	4.9	4.5	4.4	3.5	5.6	5.5	4.55–5.25	4.20–4.80
	1957	4.5	4.4	4.1	3.6	5.3	5.0	4.30–4.70	4.15–4.65
	1958	4.8	4.3	4.1	3.7	5.85	5.0	4.50–5.10	4.05–4.55
Shemonaikha (control)	1958	4.9	4.5	4.2	3.6	5.7	5.5	4.60–5.20	4.15–4.85
		Hemoglobin amount (%)							
Semipalatinsk region	1956	74	66	61	51	89	74	69–79	61–71
	1957	73	65	60	53	83	78	68–78	61–69
	1958	79	71	73	62	85	75	76.5–81.5	67.5–74.5
East Kazakhstan region	1956	78	71	70	65	86	82	74–82	69–73
	1957	80	75	71	64	98	86	75–85	71–79
	1958	82	67	62	55	83	77	69–75	64–70
Shemonaikha (control)	1958	75	70	68	60	83	78	71–79	66.5–73.5

Increased leukopenia was also noted in the white blood counts of the East Kazakhstan inhabitants who had been examined in 1956 in comparison to control (24.5% vs.10.7%), and a general shift in the number of leukocytes to lower indices was evident (tables 24 and 25). To a greater extent this was due more to decreased neutrophils rather than lymphocytes and is confirmed by data in table 26. In 1957, leukopenia decreased to 14.8% in comparison to 1956 data (table 24). However, in this case a

Table 24. Number of examined inhabitants of Semipalatinsk and East Kazakhstan region settlements and control settlement of Shemonaikha with normal and other than normal number of leukocytes, 1956–1958.

		Individuals with leukocytes (%)		
Region/settlement	Year	Normal	Above normal	Below normal
Semipalatinsk	1956	67.0	25.8	7.2
	1957	55.9	15.1	29.0
	1958	56.4	26.4	17.2
East Kazakhstan	1956	60.5	15.0	24.5
	1957	72.9	12.3	14.8
	1958	65.4	24.8	9.8
Shemonaikha (control)	1958	65.2	24.1	10.7

Table 25. Leukocytes in blood of examined Semipalatinsk and East Kazakhstan region inhabitants and control settlement Shemonaikha, 1956–1958.

Region/settlement	Year	Leukocytes in blood, 1,000/mm^3 Average	Minimum	Maximum	Zone of wide normal
Semipalatinsk	1956	7.0	4.3	11.7	5.8–8.2
	1957	5.8	2.8	13.5	4.4–7.2
	1958	6.5	4.2	10.9	5.1–7.9
East Kazakhstan	1956	6.1	4.0	11.6	5.1–7.1
	1957	6.1	4.2	8.7	5.1–7.1
	1958	6.8	4.3	11.7	5.7–7.9
Shemonaikha (control)	1958	6.7	4.4	12.3	5.45–7.95

rather high percentage of both absolute and relative neutropenia was observed—confirming a depression in granulopoiesis (table 26). In 1957, white blood counts in the examined East Kazakhstan region did not differ from control.

The erythrocyte and platelet counts in the examined inhabitants of this region showed some residual signs of erythropoiesis (table 22), and the amplification of thrombopoiesis observed earlier was replaced by an insignificant increase in the number of cases of thrombopenia (table 27).

In 1956, the red blood counts in Semipalatinsk inhabitants showed a tendency to shift the number of erythrocytes to lower values (table 23).

Table 26. Differential leukocyte counts in contaminated and control settlements,1956–1958.

	Individuals with normal or other than normal contents in white blood cells														
	Neutrophils (absolute)			Neutrophils (relative)			Stab (relative)			Leukocytes (absolute)			Leukocytes (relative)		
Year	Normal	Above normal	Below normal	Normal	Above normal	Below normal	Normal	Above normal	Below normal	Normal	Above normal	Below normal	Normal	Above normal	Below normal
Semipalatinsk region															
1956	69.6	24.2	6.2	84.7	8.5	6.8	41.9	57.0	6.1	48.0	40.7	11.3	54.2	34.0	11.8
1957	59.0	12.0	29.0	82.9	4.8	12.3	80.7	6.9	12.4	54.2	31.3	14.5	45.4	46.9	7.7
1958	63.2	17.5	19.3	84.2	1.7	14.0	86.0	7.0	7.0	45.6	49.2	5.2	42.2	52.6	5.2
East Kazakhstan region															
1956	66.0	12.0	22.0	84.0	3.0	13.0	73.0	21.9	6.0	58.0	34.0	8.0	45.0	51.0	4.0
1957	58.8	2.5	38.7	58.8	-	41.2	75.0	12.9	12.5	38.8	60.0	1.2	28.7	68.8	2.5
1958	68.6	15.7	15.7	82.8	3.1	14.1	82.0	8.3	9.7	42.5	52.3	5.3	46.2	49.2	4.6
Shemonaikha (control)															
1958	70.0	16.0	14.0	83.0	2.7	14.3	88.4	7.1	4.5	39.4	54.4	6.2	50.0	48.2	1.8

Table 27. Relative values of thrombocyte counts in contaminated and control settlements, 1956–1958.

		Individuals with thrombocytes (%)		
Region/settlement	Year	Normal	Above normal	Below normal
Semipalatinsk	1956	49.0	16.7	34.3
	1957	35.0	7.5	57.5
	1958	55.6	24.0	20.4
East Kazakhstan	1956	52.0	47.0	1.0
	1957	38.1	61.9	-
	1958	56.8	26.4	16.8
Shemonaikha (control)	1958	50.0	40.0	10.0

The percentage of erythropenia was low and increased notably (almost by 3 times) in 1957: from 5.6% for males and 9.0% for females in 1956 to 17.8% for males and 23.0% for females in 1957 (table 22). In 1958, normalization was observed in the erythrocyte contents of the peripheral blood and did not differ much from control (table 22). This normalization took place in the background of a higher number of reticulocytes.

Compared to 1956 and 1957, a considerable increase was observed in the number of individuals with higher hemoglobin contents in Semipalatinsk in 1958 (table 23). A shift in the number of leukocytes in 1956 to higher values was observed (table 25). From our point of view, this was due without exception to the increased absolute and relative number of neutrophils and the decreased absolute and relative amount of neutropenia (table 26). As for lymphocytes, a shift was evident in lymphopenia in both absolute and relative units.

In 1957 in the Semipalatinsk region, changes in white blood were opposite in character compared to 1956. There was a high percentage of leukopenia—from 7.2% in 1956 to 29.0% in 1957, almost three times greater than this index in the control (10.7%; table 24). The percentage of relative neutropenia in 1957 was almost twice that in 1956 (6.8% in 1956 and 12.3% in 1957; table 26). In 1958, a tendency was observed in the return of white blood indices to normal although leukopenia remained increased (tables 24-26).

During the three years when the inhabitants of Semipalatinsk and East Kazakhstan regions were examined, considerable changes in the blood were observed. In 1956, the number of thrombocytes was below normal in 34.4% of those examined in Semipalatinsk, in the control settlement it was 10%, and in East Kazakhstan only 1%. In 1957, it was noted that the number of thrombocytes in those examined in the Semipalatinsk region was 1.5 times greater compared to 1956 (34.3% in 1956, 57.5% in 1957; table 26) with a change in the normal range from 178,000/cc to 262,000/cc in 1956 to 120,000/cc–240,000/cc in 1957 (table 28). In 1958 the quantitative indices characterizing thrombopoiesis were normal in comparison with previous years. However, the percentage of thrombopenia remained twice as high as control (table 26), and the normal range was low (200–300 thousand/cc; table 28).

The results of the analysis and comparison of hematological data after the examinations of the inhabitants of the Semipalatinsk and East Kazakhstan regions who lived in the contaminated areas confirm the normalization of peripheral blood indices in 1958 compared to 1956 and 1957. There were no abrupt changes in the quantitative contents of peripheral blood that would confirm hemopoiesis.

Instability in white and red blood cell counts of the inhabitants in both regions and persistent suppression of thrombopoiesis of the inhabitants in the Semipalatinsk region cannot be explained by the dynamics of somatic disease changes for the 3-year observation period only. To a certain extent they might have been coupled with radiation impact in the areas contaminated with radioactive substances after nuclear weapons tests in the atmosphere at the Semipalatinsk test site.

Table 28. Absolute thrombocyte counts in contaminated and control settlements, 1956–1958.

Region/settlement	Year	Number of thrombocytes, 1,000 mm^3			
		Average	Minimum	Maximum	Wide normal zone
Semipalatinsk	1956	220	115	400	178–262
	1957	180	50	440	120–240
	1958	250	160	390	200–300
East Kazakhstan	1956	300	230	410	270–330
	1957	320	220	400	290–350
	1958	270	150	405	230–310
Shemonaikha (control)	1958	290	120	480	240–340

Conclusion

This report presents the results of the study, analysis, and summary of data that were acquired in complex examinations of inhabited settlements in the Semipalatinsk and East Kazakhstan regions in 1956-1958. These territories were contaminated in different years with radioactive substances after nuclear tests in the atmosphere at the Semipalatinsk test site. The complex radiological and medical examinations were aimed at the study of the radiation/hygiene environment in the areas of radioactive contamination and at identification of its impact on the health of the population that lived in these regions.

The analysis of the data on the character and impact of the radiation fallout on the health of the population confirms that in addition to external gamma-exposure there was intake of radioactive substances via inhalation (radioactive dust) and ingestion into the alimentary canal when contaminated food and water were consumed. However, the major hazard was gamma radiation.

After the first test in 1949, cases of skin lesions were noted in a small group of inhabitants but there were no records of symptoms of radiation illness even though cowboys and field workers harvesting millet had close contact with nuclear explosion products.

The results of the analysis of the complex medical examinations have revealed that among the inhabitants of the contaminated areas there were no cases of acute or chronic forms of radiation sickness recorded. It was also noted that all observed deviations in population health were nonspecific for "radiation impact" because the deviations were noted both in people living along the nuclear explosion traces and in control settlements. The degree of symptoms recorded does not correlate with exposure doses.

In view of the complete absence of clearly diagnosed cases of acute and chronic forms of radiation sickness, various observed functional changes in the state of the nervous system (asthenovegetative syndrome, asthenic state, vegetative dysfunction) as well as the changes in the peripheral blood pattern (leukopenia, leukocytosis, thrombopenia, thrombocytosis, etc.) cannot be considered as changes caused only by the impact of ionizing radiation.The majority of the population in the surveyed areas displayed general somatic and infectious diseases (tuberculosis, brucellosis, etc.) that cause great changes in the body, including functional changes of the nervous system, changes in peripheral blood, etc. It must be noted that these diseases originated under the impact of the extremely unsanitary living conditions of the local people. The diet of the people was monotonous and lacked vitamins, and the insufficient water for household needs hindered the people in observing elementary rules of personal hygiene.

Data from the 1956–1958 clinical/hematological examinations of the population provide information about the normalization in 1958 (compared to 1956 and 1957) of the main indices characterizing population health, especially the indices of peripheral blood. However, there are grounds that justify the premise that the observed changes in individual clinical/hematological indices (except for those due to sanitary and household conditions) were definitely impacted by radioactive fallout in the Semipalatinsk and East Kazakhstan regions during nuclear tests in the atmosphere at the Semipalatinsk test site.

Proposals for Future Activities

One report cannot cover all of the analysis results of the available archived material on the complex population examinations done in the 1950s and 1960s in the territory of the Republic of Kazakhstan.

This report, prepared under Defense Nuclear Agency Contract Number DNA 001-94-C-0121, provides the summarized results of the analysis of the complex population examinations undertaken in the Semipalatinsk and East Kazakhstan regions in 1956, 1957, and 1958, neglecting the description of the radiogenic environment in individual inhabited settlements as well as the impact on their inhabitants' health.

From our point of view, assessment of the atmospheric nuclear test impact on population health and the data acquired in the examination of the inhabitants of the three most contaminated settlements in the Semipalatinsk region—Dolon, Kainar and Sarzhal—would be of significant interest. Analysis, summary, and presentation of the dynamic results could be the goal of further research in this field.

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13. ABSTRACT *(Maximum 200 words)*

This research covers archived results of complex medical examinations done in the 1950s and 1960s by the Ministry of Health (Minzdrav) of the Union of Soviet Socialist Republics (USSR). Inhabitants of several Kazakhstan regions were contaminated in different years by radioactive fallout from atmospheric nuclear tests at the Semipalatinsk test site. The demand for analyzing the archives came about because the health status of the population had deteriorated, and the incidence of cancer and cancer mortality had increased in Kazakhstan and other eastern regions of the Russian Federation (Altai district, the Republic of Altai, and others).

Although clinical and hematological examinations noted negligible variations in the indices of peripheral blood, these were of a reactive character. They could have been caused by the impact of radioactive substances on the human body; however, no changes characteristic of radiation sickness were revealed. Also, functional deviations noted in certain organ systems could not be attributed to radioactive fallout because similar deviations were also observed in somatic and infectious diseases.

The summary and analysis of the archives with their complex medical examinations of the population in the contaminated territories allow a more objective assessment of the impact of the atmospheric nuclear tests on the health of populations in different regions.

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